CEMENT
AND
CEMENT MANUFACTURE

PUBLISHED 20TH OF EACH MONTH. PRICE 1/- A COPY. ANNUAL SUBSCRIPTION 12s. POST FREE.

PUBLISHED BY CONCRETE PUBLICATIONS LTD., 20, DARTMOUTH STREET, LONDON, S.W.1.
TELEPHONE: VICTORIA 4581.
TELEGRAPHIC ADDRESS: CONCRETIUS, PARL, LONDON.

PUBLISHERS OF
"CONCRETE & CONSTRUCTIONAL ENGINEERING"
"CONCRETE BUILDING & CONCRETE PRODUCTS"
"CEMENT & CEMENT MANUFACTURE"
"THE CONCRETE YEAR BOOK"
"CONCRETE SERIES" BOOKS, ETC.

VOLUME 5. NUMBER 1 JANUARY 1932

Publisher's Notice.

It is with very sincere regret that the publishers of CEMENT AND CEMENT MANUFACTURE have come to the conclusion that while the present world-wide dislocation of trade exists it will be impossible to continue the publication of this journal in its International form. The experiment was a novel venture, but it was one which fully justified itself by the service it rendered to the cement industry in presenting to most of the cement-making countries of the world, in their own languages, the results of the researches and manufacturing developments of other nationals. During the two years of its publication in four languages the journal has received the enthusiastic support of cement makers throughout the world. But the present depression, which could not have been foreseen two years ago, when CEMENT AND CEMENT MANUFACTURE was first published in its International form, has made international trade so difficult that, for the time being at any rate, we feel it is impossible to continue publication in four languages.

These difficult times have in no way affected the circulation of the journal, which has continued steadily to increase, and, as the English language is understood by most cement makers and their engineers and chemists throughout the world, we look forward to no reduction in the number of readers of the journal. The only difference will be that we shall be spared the cost of providing readers abroad with translations in their own languages, an advantage which we know has been greatly appreciated.

Readers can be assured that there will be no falling off in the quality of the articles published in CEMENT AND CEMENT MANUFACTURE. During the period the journal has been published in four languages an extensive international group of authoritative writers on all phases of cement production has been attracted to its pages, and these authorities will continue to collaborate with us, their contributions being translated and published in the English language only. Thus, although published in one language only, CEMENT AND CEMENT MANUFACTURE will retain an international character in its contents.

It is our hope that this change will be a temporary one only and that when world conditions improve it may again be possible to serve our friends abroad by publishing this journal in four languages.

691.052
C 33
592582
312640

THE JOHN CRERAR LIBRARY

Heat Economy in the Cement Industry.—1.

By Dr. HANS BUSSMEYER.

The Theoretical Heat Requirement of Clinker Burning.

THE theoretical heat requirement is defined as the heat necessary to burn a unit quantity of clinker in an ideal kiln, assuming that the clinker is produced at 0 deg. C. from raw meal at 0 deg. C., and that the waste gases leave the kiln at 0 deg. The theoretically ideal kiln is free from radiation, conduction, and convection losses. In such a kiln the heat used for increasing the temperature of the material is balanced by the heat evolved on cooling, and the heat consumed is limited to that required for changing the state of aggregation, or the chemical and physical structure of the material. On the other hand, exothermic chemical reactions can occur which reduce the heat consumption.

Thus only two phases of the complete process occurring in the kiln come into consideration for the evaluation of the heat requirement of clinker burning:

(1) The evolution of the CO_2 of the $CaCO_3$ and $MgCO_3$ contained in the raw material.
(2) Clinkering.

The first of these is an endothermic, or heat-absorbing, reaction. The heats of decomposition of both these compounds are established; they are -425 kcal. per 1 kg. $CaCO_3$ (-765 B.T.U. per lb.)[1] and -215 kcal. per 1 kg. $MgCO_3$ (-387 B.T.U. per lb.) respectively.

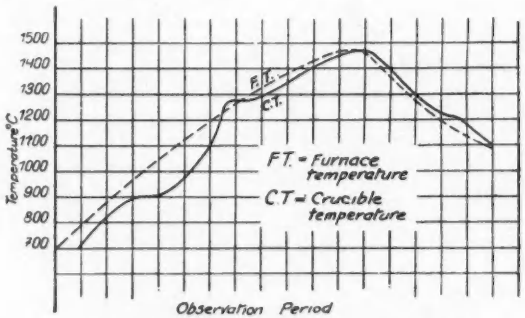


Fig. 1.—Diagram given by Dyckerhoff.

According to Nacken[2] and Kühl[3] clinkering may be subdivided into two phases, called by Kühl "fire shrinking" and "sintering." He considers fire shrinking to be an exothermic reaction, *i.e.*, one proceeding with the evolution of heat, and sintering endothermic. It is now generally accepted that exothermic reactions occur during clinkering, but determinations of the amount of heat liberated vary considerably. Tschernobaëff,[4] using a bomb calorimeter, found the value $+115$ to $+118$ kcal. per kg. $CaCO_3$, and mentions that his product was "well fused."

---

[1] It will be useful to remember in the following chapters that 1 kcal. = 3.96 B.T.U., and 1 kcal. per kg. = 1.8 B.T.U. per lb.
[2] *Zement*, Vol. 11, p. 245, 1922.
[3] *Zement*, Vol. 11, p. 454, 1922.
[4] *Z. f. angew. Chemie*, Vol. 24, p. 337, 1911.

Nacken, by extending his experiments to include fused clinker, obtained the value 142 kcal. per kg. clinker, a result higher than that of Tschernobaëff for raw meal of normal composition. Le Chatelier found a still higher value, namely, 149 kcal. per kg. $CaCO_3$. Since in technical practice fusion does not occur, Nacken adopted the results he obtained at 1,250 to 1,300 deg. C., at which he found a heat of reaction 100 kcal. per kg. clinker (180 B.T.U. per lb.), and we may regard this as the best result yet obtained.

W. Dyckerhoff[5] burnt a raw meal of the following percentage composition in a crucible in an electric furnace. Fig. 1 shows the heating and cooling curves of the furnace and crucible.

	Raw meal.
CaO	65.65
SiO_2	20.56
Al_2O_3	6.54
Fe_2O_3	3.10
MgO	1.94
SO_3	1.71
Alkalis	0.41

The dissociation of $CaCO_3$ takes place at 910 deg. C., after which the crucible curve rapidly rises, cutting the furnace curve at 1,285 deg., thus demonstrating the exothermic character of the reaction. Partial fusion of the charge then obviously occurs with further absorption of heat. It is interesting to find that in the right-hand branch of the curve, which relates to the cooling of the clinker, this latent heat of fusion absorbed at 1,285 deg. is given up, at any rate partially, at 1,215 deg.

If we now calculate for raw mixes of various compositions the heat required for the expulsion of CO_2, we obtain: For a raw mix containing 73.2 per cent. $CaCO_3$, 1,000 kg. of clinker require 1,503 kg. of dry raw material, consisting of

1,100 kg. $CaCO_3$	= 616.5 kg. CaO		+ 483.5 kg. CO_2
37 kg. $MgCO_3$	= 17.5 kg. MgO		+ 19.5 kg. CO_2
366 kg. other constituents	= 366.0 kg. other constituents		—
1,503 kg.	= 1,000.0 kg. clinker		+ 503.0 kg. CO_2

CO_2 from $CaCO_3$ = 1,100 × 425 = 467,500 kcal.
CO_2 from $MgCO_3$ = 37 × 215 = 7,955 kcal.

475,455 kcal.

For a raw mix containing 76 per cent. $CaCO_3$, 1,000 kg. of clinker require 1,532 kg. of dry raw material consisting of

1,165 kg. $CaCO_3$	= 652.5 kg. CaO		+ 512.5 kg. CO_2
37 kg. $MgCO_3$	= 17.5 kg. MgO		+ 19.5 kg. CO_2
330 kg. other constituents	= 330.0 kg. other constituents		—
1,532 kg.	= 1,000.0 kg. clinker		+ 532.0 kg. CO_2

CO_2 from $CaCO_3$ = 1,165 × 425 = 495,125 kcal.
CO_2 from $MgCO_3$ = 37 × 215 = 7,955 kcal.

503,080 kcal.

[5] *Zement*, Vol. 14, p. 200, 1925.

For a raw mix containing 78 per cent. $CaCO_3$, 1,000 kg. of clinker require 1,552 kg. of dry raw material consisting of

1,210 kg. $CaCO_3$	= 677.5 kg. CaO		+ 532.5 kg. CO_2
37 kg. $MgCO_3$	= 17.5 kg. MgO		+ 19.5 kg. CO_2
305 kg. other constituents	= 305.0 kg. other constituents		—
1,552 kg.	= 1,000.0 kg. clinker		+ 552.0 kg. CO_2

CO_2 from $CaCO_3$ = $1,210 \times 425 = 514,250$ kcal.

CO_2 from $MgCO_3$ = $37 \times 215 = 7,955$ kcal.

522,205 kcal.

If Nacken's value of 100 kcal. per 1 kg. clinker is accepted for the exothermic effect of clinkering, the theoretical heat requirement for burning clinker varies between 375,455 and 422,205 kcal. per 1,000 kg., depending on the $CaCO_3$ content of the raw mix. It will be sufficiently accurate if the value 420,000 kcal. per 1,000 kg. (756,000 B.T.U. per 1,000 lb.) clinker is adopted in the heat balances in this series of articles.

The calculations of the heat requirement of clinker burning found in the literature endeavour to account for the whole of the phenomena taking place in the kiln, and may be summarised as follows:

I.—HEAT ABSORBED.

(*a*) Heating the raw materials from 0 deg. C. to the temperature at which CO_2 is expelled, *viz.*, 900-950 deg. C.

(*b*) Expulsion of CO_2 from $CaCO_3$ and $MgCO_3$.

(*c*) Heating the calcined material from 900-950 deg. to the temperature at which it is completely burnt, *viz.*, about 1,450 deg. C.

II.—HEAT RECOVERED.

(*a*) Exothermic effect of clinker formation.

(*b*) Heat contained in the CO_2 expelled at 900-950 deg. C.

(*c*) Heat contained in the clinker at 1,450 deg. C.

The difference between I and II represents the theoretical heat required for the formation of clinker.

To obtain in this way results beyond question, an accurate knowledge of the mean specific heats is necessary for the calculation of the quantities I*a*, I*c*, and II*c*. The temperature intervals of the individual phenomena are so great that constant values of the specific heats do not suffice.

The following formulæ were at one time in use:

$$\text{Specific heat of raw material} = 0.194 + 0.000077t$$

$$\text{Specific heat of clinker} = 0.181 + 0.00007t$$

Both these formulæ represent the specific heats as linear functions of the temperature t, but so simple a relation appears improbable.

Hartner[6] has recently determined the instantaneous specific heats of clinker, and his results are given in curve 1 of Fig. 2. Between 900 and 1,000 deg. C. there is a point of inflexion. Apparently the clinker begins to melt at this point, so that the latent heat of fusion is added to the specific heat; this was also obvious in the clinker cooling curve in Dyckerhoff's experiment.

The dotted line in Fig. 2 indicates the probable continuation of the curve of instantaneous specific heats if the latent heat of fusion is eliminated; curve 2 of Fig. 2 gives the mean specific heats of clinker obtained from curve 1. For comparison, the formula first given is plotted as curve 3, while curve 4

[6] *Zement*, Vol. 16, p. 41, 1927.

represents the results of Dr. W. P. White, of the Bureau of Standards, Washington. The Hartner curve, which was obtained in the Physical Institute of Giessen University, may be accepted with confidence. Unfortunately, however, it does not extend into the region of high temperatures above 900 deg. C.

It follows that we have not yet completely at our disposal the equipment necessary for a detailed statement of the heat distribution in the phenomena occurring in the theoretical kiln. It may be shown, however, that the theoretical heat requirement may be obtained with sufficient reliability if we work on the following considerations: (1) In the ideal kiln pure heating processes must be balanced by pure cooling processes, irrespective of the manner in which the specific heats of the various materials in various states of aggregation may vary. (2) The latent heat of fusion absorbed in clinker formation is again set free when the clinker cools.

Blast-furnace cement clinker, which is manufactured from limestone and blast-furnace slag, has a much lower theoretical heat of formation than Portland cement clinker, since, as a result of the high lime content of the slag, the amount of $CaCO_3$ to be decomposed per 1,000 kg. clinker is smaller. If it be assumed that the slag contains 42 per cent. CaO and the magnesia-free limestone 95 per cent. $CaCO_3$, 1,380 kg. of dry raw materials (76 per cent. $CaCO_3$) are required per 1,000 kg. clinker, 380 kg. CO_2 must be expelled, corresponding to 863.6 kg. $CaCO_3$ in the raw material. The theoretical heat requirement is thus $863.6 \times 425 - 100{,}000 = 266{,}830$ kcal. per 1,000 kg. clinker

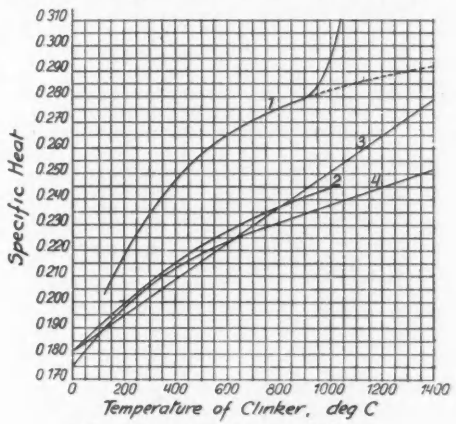


Fig. 2.—Specific Heat of Clinker.

(480,300 B.T.U. per 1,000 lb.). In actual practice the heat consumption of the kiln is much smaller in blast-furnace cement than in Portland cement manufacture.

The Heat Balance Equation of the Kiln in Practice.

According to Rosin[7], the following equation gives the amount of heat developed by a given fuel:

$$J_1 = C/V \text{ kcal. per cu. metre} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

[7] "The *It* Diagram of Combustion," Berlin, 1929.

where C is the calorific value of the fuel in kcal. per kg. and V is the volume in cubic metres of the gases of combustion obtained from 1 kg. of fuel. Since V depends on the excess air used for combustion, J_1 is dependent upon the calorific value C and upon the degree to which combustion is complete. Rosin has further shown that the heat content of 1 cubic metre of combustion gases is independent of the nature of the fuel and dependent only upon the temperature.

All the following calculations and results refer to a standard fuel, coal or coal dust, of calorific value 7,500 kcal. per kg. (13,500 B.T.U. per lb.) and of percentage composition C=78, H_2=5, O_2=8, H_2O=2.

During burning the combustion gases are cooled from the original heat content VJ_1=C to VJ_2 kcal. per kg. Thus the heat quantity $(VJ_1 - VJ_2)$ is consumed, *i.e.*, partly utilised and partly lost, while the quantity VJ_2 remains in the waste gases.

If x kg. fuel is used per 1,000 kg. clinker, the heat developed is:

$$x\,C = x\,VJ_1 \text{ kcal.} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

This heat is distributed in the cement kiln as follows: (1) The theoretical heat consumption calculated must be allowed for; this will be designated q_{th}. (2) The whole of the exit gases must leave the kiln at the temperature t_g.

The heat thus accounted for is made up as follows:

(*a*) The heat content of the gases of combustion, amounting to $x\,VJ_2$ kcal. per 1,000 kg. clinker, where VJ_2 is dependent on the amount of excess air and the temperature t_g.

(*b*) The heat content of the CO_2 expelled from the raw materials, depending on the temperature, t_g. This quantity of heat will be designated c.

(*c*) The heat content of the steam expelled from the raw meal. This also depends on t_g. The heat content of 1 kg. steam is composed of the latent heat, 595 kcal., and the superheat, w kcal.

(3) All remaining losses must be allowed for. These will be taken as a per cent. of the total heat used, or $\frac{a}{100} \times x\,C$, or for the standard fuel $75\,a \cdot x$ kcal. per 1,000 kg. clinker.

It will be assumed that 1,550 kg. of dry raw material are required for 1,000 kg. of clinker, so that 550 kg. of CO_2 will be driven off.

Let the water content of the moist raw meal be b per cent. by weight. Then $\frac{1{,}550\,b}{100-b}$ kg. steam must be evolved per 1,000 kg. clinker, and will leave the kiln with a temperature t_g.

We then derive the following heat balance equation:

$$x\,VJ_1 = q_{th} + x\,VJ_2 + \frac{1{,}550\,b}{100-b}(595 + w) + c + 75ax \quad \ldots\ldots (3)$$

For standard coal of calorific value 7,500 kcal. per kg. the fuel consumption x is thence derived as

$$x = \frac{q_{th} + c + \frac{1{,}550\,b}{100-b}(595 + w)}{7{,}500 - VJ_2 - 75\,a} \text{ kg.} \quad \ldots\ldots\ldots (4)$$

assuming that the exit gas temperature t_g and the heat losses a are known. The values of c, $1{,}550\,b/(100-b)$, w and $(595+w)$, as well as V and J_2, are given in Tables 1-5.

In calculating V it is assumed that 1 kilogramme molecule (Mol.) of the gases of combustion occupy 24 cubic metres at a certain standard temperature and pressure. This value is adopted throughout because it gives extremely simple numerical values in the calculations.

TABLE I.

HEAT CONTENT c (IN KCAL.) OF 550 KG. = 300 CU. M. CO_2, AT VARIOUS TEMPERATURES.

t_g° C.	100	200	300	400	500	600	700	800	900	1,000
c kcal.	11,500	23,800	37,000	50,900	65,200	79,900	95,200	110,900	126,800	142,500

TABLE II.

QUANTITY OF WATER, $\frac{1{,}550\,b}{100 - b}$ KG.

b %	8	9	10	11	12	14	16	18	20	22	24
$1{,}550 \cdot \frac{b}{100 - b}$ kg.	135	154	172	192	212	253	296	340	387	436	490

b %	26	28	30	32	34	36	38	40	42	44	46
$1{,}550 \cdot \frac{b}{100 - b}$ kg.	544	603	664	729	798	873	950	1,034	1,122	1,219	1,320

TABLE III.

HEAT CONTENT w AND $(595 + w)$ KCAL. OF 1 KG. STEAM AT VARIOUS TEMPERATURES.

t_g ° C.	100	200	300	400	500	600	700	800	900	1,000
w kcal.	46	93	140	188	237	286	335	387	441	495
$(595 + w)$ kcal.	641	688	735	783	832	881	930	982	1,036	1,090

TABLE IV.

VOLUME V CU. M. AND WEIGHT OF GASES OF COMBUSTION FROM 1 KG. STANDARD COAL. (CALORIFIC VALUE 7,500 KCAL. PER KG.) WITH VARIOUS AMOUNTS OF EXCESS AIR, λ.

λ	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
Cu. m.	8.96	10.67	12.39	14.10	15.81	17.53	19.24	20.95
Kg.	11.23	13.29	15.34	17.40	19.46	21.52	23.57	25.63

TABLE V.

HEAT CONTENT (KCAL.) OF 1 CU. M. GASES OF COMBUSTION AT VARIOUS TEMPERATURES t_g AND AMOUNTS OF EXCESS AIR, λ.

λ	Temperature t_g deg. C.					
	200	400	600	800	1,000	1,200
1.0	62.5	129.8	199.0	269.5	343.5	419.0
1.2	62.1	128.7	197.1	266.9	340.0	414.6
1.4	61.7	127.6	195.2	264.3	336.5	410.2
1.6	61.3	126.5	193.3	261.7	333.0	405.8
1.8	60.9	125.4	191.4	259.1	329.5	401.4
2.0	60.5	124.3	189.5	256.5	326.0	397.0
2.2	60.1	123.2	187.6	253.9	322.5	392.6
2.4	59.7	122.1	185.7	250.3	319.0	388.2

The excess air factor λ gives the multiple of the theoretical quantity of air used for combustion. With theoretically perfect combustion $\lambda = 1$. The loss factor α includes all heat losses except that due to the exit gases. It comprises:

(1) Losses from the kiln plant due to radiation, conduction and convection.
(2) The heat content of the clinker issuing from the cooler.
(3) The heat contained in the dust carried out of the kiln by the gases. On the one hand this dust, which is at high temperature, contains an important quantity of heat; on the other hand, it has more or less taken part in the kiln reactions and has thus consumed heat.
(4) The loss of heat due to unburnt fuel which leaves the plant with the clinker.
(5) The heat loss due to incomplete combustion, *i.e.*, formation of CO or of soot instead of CO_2.

Chemical Composition of the Kiln Waste Gases.

One kilogramme of fuel contains C kg. carbon, H_2 kg. hydrogen, O_2 kg. oxygen, and W kg. water. Thus, remembering that 1 Mol. of all gases occupies 24 cubic metres at standard temperature and pressure.

C kg. carbon give 2 C cu. m. or $\frac{11}{6} \times 2$ C kg. CO_2.

C kg. ,, ,, 2 C cu. m. or $\frac{7}{6} \times 2$ C kg. CO.

H_2 kg. hydrogen + W kg. water give $\frac{4}{3}(9\,H_2 + W)$ cu. m

or $(9\,H_2 + W)$ kg. H_2O.

The oxygen required is:

For C to form CO_2 , $24 \times \frac{C}{12} = 2$ C cu. m.

,, C ,, ,, CO , $12 \times \frac{C}{12} = 2$ C cu. m.

,, H_2 ,, ,, H_2O , $24\left(\frac{H_2}{4} - \frac{O_2}{32}\right) = 6\left(H_2 - \frac{O_2}{8}\right)$ cu. m.

If $\epsilon/100$ of carbon burns to form CO_2, and $(100-\epsilon)/100$ to form CO, and the whole of the hydrogen burns to H_2O, the minimum volume of oxygen required is:

$$O_{min} = \frac{\epsilon}{100} \cdot 2\,C + \frac{100 - \epsilon}{100} \cdot C + 6\left(H_2 - \frac{O_2}{8}\right) \text{ cu. m.}$$

$$O_{min} = \frac{100 + \epsilon}{100} \cdot C + 6\left(H_2 - \frac{O_2}{8}\right) \text{ cu. m.} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Since the combustion takes place in air and not in oxygen, each cubic metre of oxygen in the combustion gases will be accompanied by 79/21 cubic metres of nitrogen. Equation (6) gives the volume of "dry" gases obtained from 1 kg. fuel, *i.e.*, the total volume of gas exclusive of water; this is the gas as analysed by the Orsat, or other gas-analysis apparatus.

$$V_{d\min} = \frac{\epsilon}{100} \cdot 2\,C + \frac{100 - \epsilon}{100} \cdot 2\,C + \frac{79}{21} O_{\min}.$$

$$V_{d\min} = 2\,C + 3.762\,O_{\min} \text{ cu. m.} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6$$

O min. corresponds to the theoretical quantity of air.

$$A_{\min} = \frac{100}{21} \cdot O_{\min} = 4.762\,O_{\min} \text{ cu. m.} \quad \ldots\ldots\ldots\ldots (7)$$

If combustion takes place in an excess of air, the volume of dry gas is:

$$V_d = 2\,C + 3.762 \cdot O_{\min} + 4.762\,(\lambda - 1)\,O_{\min}$$
$$= 2\,C + (4.762\,\lambda - 1)\,O_{\min} \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

This amount of gas contains:

$$CO_2 = \frac{\epsilon}{100} \cdot 2\,C \text{ cu. m.} = k = \frac{2\,C\,\epsilon}{2\,C + (4.762\,\lambda - 1)\,O_{\min}} \text{ per cent.} \ldots\ldots (9)$$

$$CO = \frac{100 - \epsilon}{100} \cdot 2\,C \text{ cu. m.} = q = \frac{2\,C\,(100 - \epsilon)}{2\,C + (4.762\,\lambda - 1)\,O_{\min}} \text{ per cent.} \quad (10)$$

$$O_2 = (\lambda - 1)\,O_{\min} \text{ cu. m.} = o = \frac{100\,(\lambda - 1)\,O_{\min}}{2\,C + (4.762\,\lambda - 1)\,O_{\min}} \text{ per cent.} \ldots (11)$$

The remainder of the gas is nitrogen.

In addition to the gases of combustion, calculated above, the kiln exit gases contain 300 cubic metres CO_2 per 1,000 kg. clinker from the raw meal. If x kg. coal are burnt per 1,000 kg. clinker, $300/x$ cubic metres of CO_2 must be added to the gases resulting from burning 1 kg. coal. The volume of dry gases formed in the kiln per kg. of coal burnt is thus:

$$V'_d = \left(V_d + \frac{300}{x}\right) \text{cu. m.}$$

The CO_2 developed in burning 1 kg. coal is k per cent. $= k\,V_d/100$ cubic metres.

In addition $300/x$ cubic metres CO_2 is obtained from the raw meal, so that analysis of the kiln gases gives:

$$k' = 100 \left(\frac{k}{100} V_d + \frac{300}{x}\right) \Big/ V'_d \text{ per cent.}$$

$$= \frac{k\,V_d + \frac{30{,}000}{x}}{V_d + \frac{300}{x}} \text{ per cent.} \quad \ldots\ldots\ldots\ldots\ldots (12)$$

If q' is the percentage CO content and o' the percentage O_2 content of the dry kiln gases, similar calculations give:

$$q' = \frac{q\,V_d}{V_d + \frac{300}{x}} \text{ per cent.} \quad \ldots\ldots\ldots\ldots\ldots (13)$$

$$o' = \frac{o\,V_d}{V_d + \frac{300}{x}} \text{ per cent.} \quad \ldots\ldots\ldots\ldots\ldots (14)$$

These formulæ give the values in Tables 6 and 7 for standard coal.

TABLE VI.

VALUES OF V_d (CU. M.), k, q AND o (PERCENTAGES), OF THE GASES OF COMBUSTION FROM 1 KG. STANDARD COAL FOR VARIOUS VALUES OF λ AND ϵ (ORSAT MEASUREMENTS).

ϵ	λ	1.0	1.1	1.2	1.3	1.4	1.6	2.0	2.4
100	V_d	8.33	9.19	10.05	10.90	11.76	13.47	16.90	20.33
	k	18.75	17.00	15.52	14.31	13.28	11.60	9.24	7.69
	q	—	—	—	—	—	—	—	—
	o	—	1.96	3.58	4.95	6.12	8.02	10.68	12.41
90	V_d	8.04	8.86	9.68	10.50	11.32	—	—	—
	k	17.48	15.85	14.51	13.39	12.42	—	—	—
	q	1.94	1.76	1.61	1.49	1.38	—	—	—
	o	—	1.94	3.55	4.92	6.08	—	—	—
80	V_d	7.75	8.53	9.31	10.09	10.88	—	—	—
	k	16.12	14.65	13.41	12.36	11.49	—	—	—
	q	4.04	3.66	3.36	3.09	2.87	—	—	—
	o	—	1.92	3.54	4.89	6.05	—	—	—

TABLE VII.

VALUES OF V_d' (CU. M.), k', q' AND o' (PERCENTAGES), OF THE KILN GASES, FOR VARIOUS VALUES OF x, ϵ AND λ (ORSAT MEASUREMENTS).

	ϵ	100				90				80			
x	λ	1.0	1.1	1.2	1.3	1.0	1.1	1.2	1.3	1.0	1.1	1.2	1.3
200	V_d'	9.83	10.69	11.55	12.40	9.54	10.36	11.18	12.00	9.25	10.03	10.81	11.59
	k'	31.15	28.65	26.50	24.65	30.50	28.10	26.00	24.20	29.80	27.40	25.40	23.70
	q'	—	—	—	—	1.64	1.51	1.40	1.30	3.38	3.11	2.89	2.70
	o'	—	1.69	3.12	4.35	—	1.66	3.08	4.30	—	1.63	3.05	4.26
240	V_d'	9.58	10.44	11.30	12.15	9.29	10.11	10.93	11.75	9.00	9.78	10.56	11.34
	k'	29.35	26.90	24.90	23.10	28.60	26.25	24.30	22.60	27.85	25.60	23.70	22.05
	q'	—	—	—	—	1.68	1.54	1.43	1.33	3.48	3.20	2.93	2.76
	o'	—	1.72	3.19	4.45	—	1.70	3.14	4.39	—	1.68	3.12	4.35
280	V_d'	9.40	10.26	11.12	11.98	9.11	9.93	10.75	11.57	8.82	9.60	10.38	11.16
	k'	28.00	25.65	23.65	21.98	27.20	24.90	23.00	21.40	25.35	24.20	22.35	20.80
	q'	—	—	—	—	1.71	1.57	1.45	1.35	3.55	3.26	3.01	2.80
	o'	—	1.76	3.24	4.58	—	1.73	3.20	4.46	—	1.71	3.17	4.43
320	V_d'	9.27	10.13	10.99	11.84	8.98	9.80	10.62	11.44	8.69	9.47	10.25	11.03
	k'	27.00	24.65	22.80	21.10	26.10	23.90	22.10	20.55	25.25	23.10	21.35	19.85
	q'	—	—	—	—	1.74	1.59	1.47	1.36	3.60	3.30	3.04	2.83
	o'	—	1.78	3.26	4.60	—	1.76	3.24	4.50	—	1.73	3.21	4.46

Since the heat equivalent of 1 cubic metre CO is 2,840 kcal., the loss of heat due to incomplete combustion of C to form CO is easily calculated.

Example.—From Table 7, the total quantity of gas resulting from 1 kg. coal, for $\epsilon = 90$, $x = 240$, and $\lambda = 1.1$, is $V_d' = 10.11$ cubic metres, while $q' = 1.54$ per cent. Therefore, $0.0154 \times 10.11 = 0.156$ cubic metre CO is produced per kg.

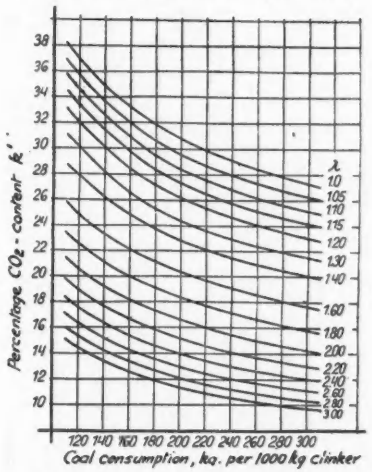


Fig. 3.—CO_2 Content of Kiln Gases, K^1.

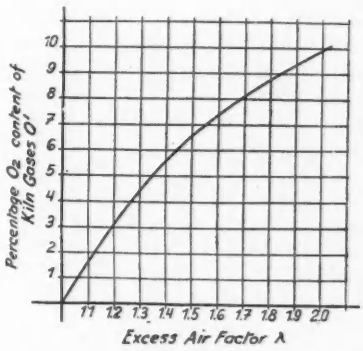


Fig. 4.

Oxygen Content of Kiln Gases, O^1.

coal, and the heat loss due to incomplete combustion is $0.156 \times 2,840 = 443$ kcal., *i.e.*, $100 \times \frac{443}{7,500} = 5.9$ per cent. of the total heat. This loss of heat, when expressed in kcal. per kg. coal or as a percentage of the total obtainable heat (see Table 8), is independent of x and λ. If, however, this heat loss is expressed in kcal. per 1 per cent. of CO formed, the values given in Table 9 are obtained for various values of x and λ.

TABLE VIII.

HEAT LOSS DUE TO INCOMPLETE COMBUSTION OF CARBON TO CO.

$\epsilon =$	90	80
Heat loss per kg. standard coal, kcal.	443	886
Heat loss as a percentage of the total available heat	5.9	11.8

TABLE IX.

HEAT LOSS DUE TO INCOMPLETE COMBUSTION OF C TO CO EXPRESSED IN KCAL. PER 1 PER CENT. CO FORMED.

$\epsilon =$	90					80				
$\lambda =$	1.0	1.1	1.2	1.3	1.4	1.0	1.1	1.2	1.3	1.4
$x = 200$	270	293	316	340	363	262	285	306	328	350
240	264	287	309	333	357	254	277	302	321	343
280	259	282	305	328	352	250	272	294	316	339
320	254	278	301	326	349	246	268	291	313	336

It must be remembered that the total quantity of gas per kg. coal is greater than V_d', since to the volume of dry gas must be added that of the steam formed by burning the coal and evolved from the moist raw meal or slurry. Thus, the total volume V of the gases of combustion per 1 kg. coal is:

$$V = V_d + \frac{4}{3}(9\,H_2 + W) \text{ cu. m.},$$

and the total volume of the kiln gases per kg. coal:

$$V' = V'_d + \frac{4}{3}(9\,H_2 + W) + \frac{4}{3} \cdot \frac{1{,}550}{x} \cdot \frac{b}{100 - b} \text{ cu. m.}$$

For our standard coal (see analysis on p. 6).

$$\frac{4}{3}(9\,H_2 + W) = 0.627 \text{ cu. m., so that}$$

$$V = V_d + 0.627 \text{ cu. m.} \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Table 7 gives information which is of great value in practical kiln control. It will be seen that k' is on the one hand strongly dependent on λ and ϵ, while on the other hand it is not less dependent on x. If curves are drawn showing the relation between k' and x for various values of λ, a series of similar curves will be obtained with distinct intervals between them (see Fig. 3, in which $\epsilon = 100$).

q', on the other hand, is strongly dependent only on ϵ; it is to a much less extent dependent on λ, and only very slightly dependent on x. Finally, o' is strongly affected only by variations in λ; it is only very slightly susceptible to changes in ϵ and x. Even when $\lambda = 2.4$ the difference in o' is only 0.3 per cent. for a change in x from 200 to 320. o' can thus be represented as independent of x and ϵ by a single average curve as in Fig. 4, and no error of practical importance will thereby be introduced.

It will thus be seen that a curve of the CO_2 content of the kiln gases, as given by a CO_2 recorder, can give no certain information as to whether the burning has been continuously carried out under the best conditions. In controlling the rotary kiln the burner depends solely on his eye to adjust the coal consumption, and accordingly the CO_2 record alone affords no criterion as to whether the amount of excess air at any instant is in agreement with the fuel consumption. Again, the management cannot draw definite conclusions as to the skill of the burner from the CO_2 curve, and the award of a premium to the burner cannot be unconditionally based upon the results given by a CO_2 recorder. On the other hand, the curve given by a reliable oxygen recorder provides a completely reliable indication of the quality of the burning. This may satisfactorily be amplified by determinations of CO content, although this is not absolutely necessary once the minimum oxygen content below which CO is formed has been established.

The quantity of excess air used in the modern cement kiln can be considerably reduced. It can hardly be recommended, however, especially in the rotary kiln, that λ should be reduced much below 1.2, owing to the danger of CO formation. If the value 1.2 is adopted, the flame temperature will always be sufficiently high, even when a hard burnt clinker is desired. The loss due to CO formation can very easily be greater than the advantage that can theoretically be obtained by further reduction of λ. On the other hand, it may be accepted that the adoption of $\lambda = 1.2$, or about 3.20 per cent. oxygen, avoids the possibility of incomplete combustion. It may thus be anticipated that, assuming a chimney, etc., of correct design, an oxygen content of 3 to 4 per cent. in the kiln exit gases will give completely satisfactory results.

Modern Tendencies in Cement Manufacture.

IN considering modern tendencies in cement manufacture, it must be appreciated that these are only likely to proceed in one or both of two directions, *viz.*, lower cost of production and better quality. The competition in quality has been so keen that it is safe to say that no changes have been made in the direction of lower cost at the expense of quality. It is true that progress in quality has been confined to one feature, *viz.*, strength, and, although it is a common complaint that cement users have not taken full advantage of the improved strength now available, manufacturers on their side must admit that there is still progress to be made in other directions, such as liability to contraction and efflorescence.

Taking a general view, it is indisputable that simplification is the outstanding modern tendency of cement manufacture. Simplification is seen in the adoption of compound mills instead of ball and tube mills for grinding, in the replacement

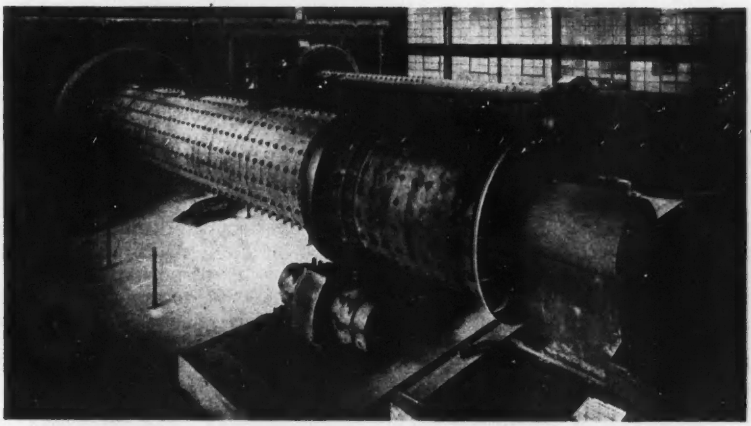
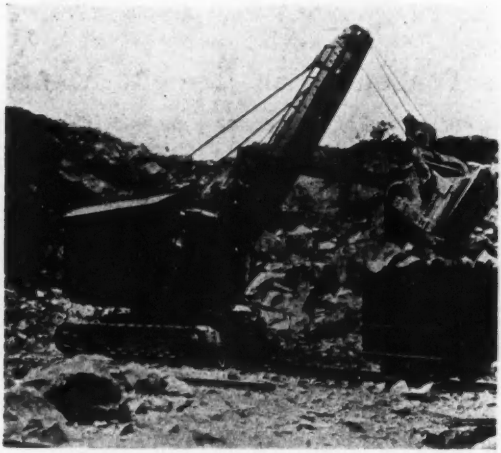


Fig. 1.—Two Raw-Material Grinding Mills, 46 ft. long by 7 ft. 3 in. diameter, preparing Slurry for 7,000 tons of Cement per week.

of coal driers and coal mills by single-unit pulverisers, and by the use of kilns with attached coolers in place of separate kilns and coolers.. Descriptions of cement works that appear in this and other journals from time to time are tending to become stereotyped because simplified factories leave little scope for variations. Simplification is also shown in the sizes of manufacturing units that are now being employed, and a factory with an output of 3,000 tons per week needs only one each of the principal machines, *viz.*, raw grinding mill, coal mill, rotary kiln, clinker grinding mill, and sack-filling machine. When it is appreciated that three sets of each unit can be placed side by side for an output of 9,000 tons per week, and that each department requires the supervision of only one man, the labour-saving resulting from simplification will be realised. A German works with a capacity of 7,000 tons per week claims to



Mechanical Excavator.

employ only 160 men, *i.e.*, over 40 tons per man per week, including repairs, laboratory, and foremen. Such labour economy would not be possible without similar adoption of large mechanical units in the raw material winning departments, and electrically driven navvies with capacities running into hundreds of tons per hour are now being employed.

It is probable that the demand for simplification has been forced by the high cost of labour in this country, not only in the cement works but in engineering establishments, leading in its turn to high prices of machinery renewals. Simplification has also been facilitated by the low cost of power, because it is certain that in some directions—notably in connection with compound mills and with rotary kilns requiring induced draft—the power consumption per ton of cement has been increased by the more modern plants as compared with the older multiple unit plants. Power can be saved by the use of high-speed centrifugal mills and air separators for grinding, but when power is cheap it is

Scraper Outfit for removing Topsoil.

usually considered that such saving is counterbalanced by the extra repairs, supervision, and complication of plant and buildings as compared with a compound tube mill.

Another tendency in cement manufacture is to make the plant less susceptible to fluctuations of human effort, both mental and manual. The almost universal use of mechanical excavating plant for raw material winning is the outstanding example of replacement of muscle by machine, or avoiding dependence on human effort, and the same result is obtained by systems of mechanical transport of coal, clinker, and other materials. In this latter connection, pneumatic transport is a modern example of simplification requiring less attention in detail than the screw conveyor and bucket elevator systems of past years.

Less dependence on the mental efforts of workmen is being secured by the

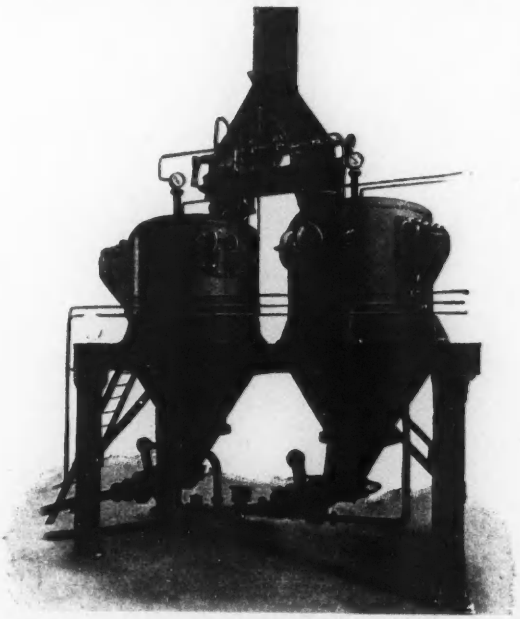


Fig. 3.—Pneumatic Pump for Slurry Transport.

installation of automatic weighing devices for feeding materials into mills, thus avoiding the judgment of the miller's eye as to quantities. More important is the installation of temperature recording and air-flow recording apparatus as well as CO_2, CO, and O recorders in connection with rotary kilns. These appliances do not render rotary kilns foolproof, but the records they produce reveal to scientific controllers the behaviour of the kilns and the steps taken by the kiln attendant to deal with defects in the smooth performance of the kilns. Granting that the maintenance of an adequate temperature in the burning zone is the *sine-qua-non*, it does not seem impossible that an optical pyrometer may be devised that will automatically indicate a cooling off, and so call the

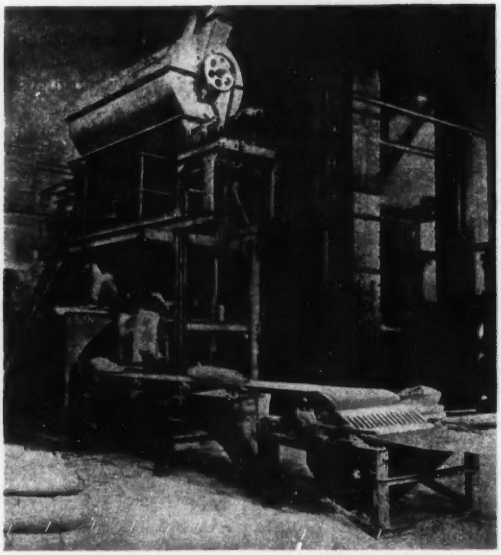


Fig. 4.—Cement Packing Plant (capacity 1,000 bags per man per hour).

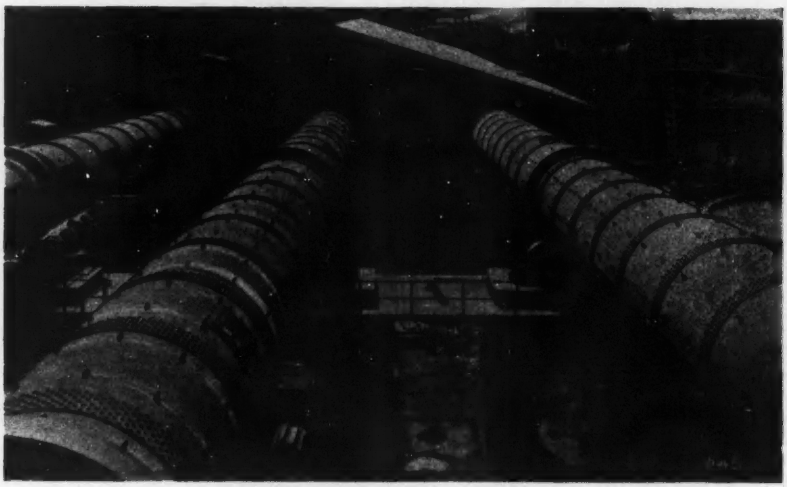


Fig. 5.—Modern Rotary Kilns.

kiln attendant's attention to the necessity for adjustment of coal or air supply after examination of the gas composition recorders. Such an apparatus would take the place of the burner's judgment as to the burning zone temperature. At the present time it must be admitted that the rotary kiln is the only process calling for a measure of skill or mental effort by the workman.

In the packing of cement it might be argued that the recent changes have been in the direction of complication when the pre-War system of filling and fastening sacks entirely by hand is compared with the somewhat intricate valve-

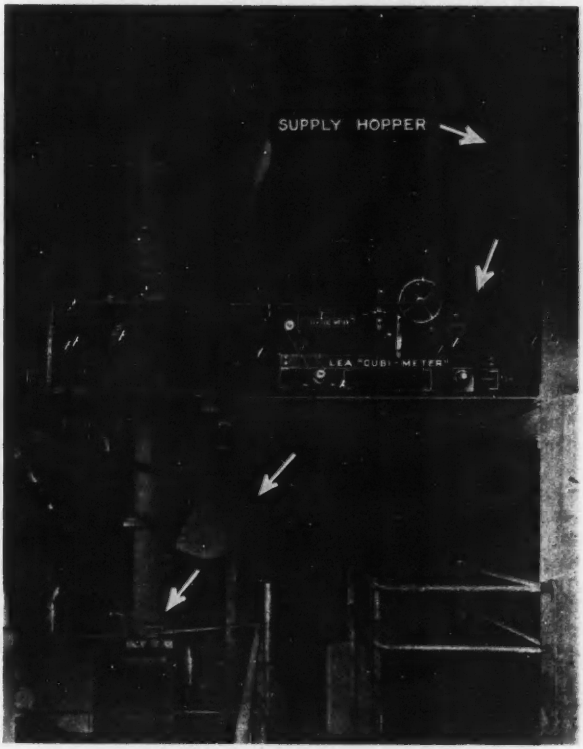


Fig. 6.—Apparatus for Measuring Coal.

packing machines, but the enormous reduction in the labour force in itself constitutes such a simplification as to make the change an overwhelming advantage.

There have been numerous systems for economy of fuel in rotary kilns, but these all introduce complications. There are some who advocate that a simple rotary kiln with slurry and fuel pumped in at opposite ends is ultimately of more advantage than kilns fitted with attachments of one sort or another. Such an argument could only be tenable when fuel is very cheap, say, in the region of 10s. per ton, but it is in districts where this price is doubled or more where

some of the modern heat-saving devices with their necessary complications call for adoption, or where the dry process must come under consideration.

The striving for simplification is again evidenced by the modern practice of buying power instead of generating it at the cement works. At large cement works there is no reason why power should not be generated as cheaply as it can be bought, but by eliminating the power-producing plant the duties of the manager and staff are lightened, and they are not called upon for the expert knowledge and supervision needed to maintain power plant at maximum efficiency.

It is hardly necessary to point out that the changes in cement manufacture, almost amounting to revolutions of detail, have only been possible by heavy capital expenditure, and the cost of cement factories based on the annual tonnage production is a very different figure to the pre-War level.

Notes from the Foreign Press.

Duration of Grinding and Setting Time of Cement. K. Koyanagi. *Zement*, Vol. 20, p. 467, 1931.

A rotary clinker was ground for various periods up to two hours in a closed ball mill. In experimental series (1) graded clinker of 15 mm. diameter was ground with 65 mm. steel balls. In series (2) graded crushed clinker of 2 mm. diameter was ground with steel cylpebs, 16 mm. by 35 mm. Gypsum corresponding to 1.2, 1.5 and 2.0 per cent. SO_3 was ground in with the clinker in both series. In both series the setting time was lowered as time of grinding was increased until at two hours the cement was flash setting. The flash-setting cement of series (1) was, however, coarser than the normal setting cement of series (2) which had been ground for only one hour. This even applied to the air elutriation results.

In a further experiment (3), crushed clinker was ground without gypsum for periods up to four hours, finely ground gypsum being added later. The setting time again fell as time of grinding increased, but the cement did not become flash setting even after four hours.

The cause of the phenomenon is not definitely established. It cannot be due to dehydration of gypsum, as the mill temperature did not exceed 70 deg. C. Experiment (3) shows that it cannot be due to the higher proportion of flour resulting from long grinding, since the four hours grinding in (3) must produce much more flour than the two hours of (1) and (2). Possibly the retarding action of gypsum is in some way reduced by long grinding in contact with the clinker.

Scaling of Cold Water Soundness Pats. E. Rissel. *Tonind. Zeit.*, Vol. 55, p. 601, 1931.

Until recently the scaling of cold water soundness test-pieces was regarded as a sign of expansion. In 1929 Haegermann showed that scaling can be induced artificially in pats of sound cement by transferring them from the moist closet to water too soon, and concluded that surface scaling had no connection with expansion. The present author considers this conclusion to be unjustified. He agrees that the early immersion of pats of sound cement in water may give rise to scaling. He presents, however, a case of a low-lime mixed cement, ground to 15 per cent. residue on the 250 (per in.) sieve, setting time 9 hours, pats of which were transferred to water after 24 hours in moist air. This showed pronounced scaling, and after 7 days the cement was proved unsound. This may be an exceptional case, but systematic research into the question is necessary.

The Hardening of Portland Cement.

DISCUSSION BETWEEN PROF. HANS KÜHL AND MR. F. F. TIPPMANN

We give below the comments by Professor Hans Kühl on the article by Mr. Tippmann in the October, 1931, number of CEMENT AND CEMENT MANUFACTURE, *and Mr. Tippmann's reply thereto, together with remarks by Dr. K. E. Dorsch.*

By PROFESSOR KÜHL.

IN CEMENT AND CEMENT MANUFACTURE for October, 1931, p. 1115, Mr. F. F. Tippmann has dealt with the hardening of Portland cement in a manner which compels me to reply. The questions arising can most rapidly be dealt with by considering the nine sections of Mr. Tippmann's summary *seriatim*.

(1) "The hydrolysis of the calcium silicates of clinker in the presence of water is complete; *i.e.*, the final products are silica gel and calcium hydroxide. This result is unaffected by the proportions of water used in mixing the cement."

With the exception of W. Michaelis, junr.,[1] who twenty-three years ago advanced the same view, all cement investigators have concluded that not free silica, but calcium hydrosilicate, is formed on hydration of Portland cement. Against Mr. Tippmann's view there is the fact that various calcium hydrosilicates, *e.g.*, okenite, plombierite, etc., occur in nature. How can the constituents of these minerals remain in combination if calcium silicates are decomposed to $Ca(OH)_2$ and SiO_2, even by saturated lime water, as Mr. Tippmann maintains?

Again, if this complete hydrolysis takes place, hydrosilicate could not be formed from lime and silica hydrates; but the latter reaction unquestionably takes place. I refer to the work of Le Chatelier,[2] Jordis and Kanter,[3] Michaelis,[4] Keisermann,[5] Pulfrich and Linck,[6] and finally of Tippmann himself, who finds (p. 1119, "C. & C.M.," 1931) "a distinct but very feeble affinity between $Ca(OH)_2$ and SiO_2," so that a "slight tendency to the formation of calcium hydrosilicate" exists. He suggests that this tendency gives rise to an adsorption compound which he compares with palladium hydride. This is an important admission, since true compounds are frequently formed on the ageing of adsorption compounds, *e.g.*, kaolin formation. And what is gained by assuming complete hydrolysis when the final result is a hardened combination of CaO, SiO_2, and H_2O?

Finally, well-defined aqueous compounds of CaO and SiO_2 can be obtained in other ways, *e.g.*, by substitution and by the hydration of water-free silicates. Lerch and Bogue[7] have given numerical evidence for the stability of various calcium hydrosilicates from measurements of hydrion concentration.

It can therefore not be doubted that statement (1) is denied by scientific evidence.

(2) "In cement mortars containing the normal quantity of water, the properties of the hydration products are entirely different from those obtained with great excess of water; as a result of the high viscosity of the former system, the products take somatoid form."

I contest the statement that mortars of normal water content have high viscosity. Mr. Tippmann is, however, right in saying that the hydration products

---

[1] *Tonind. Zeit.*, 1908, p. 62.
[2] *Ann. des Mines*, Vol. 11, p. 345, 1887.
[3] *Z. f. anorg. Chemie*, Vol. 35, pp. 82, 148, 336; Vol. 42, p. 432; Vol. 43, p. 46.
[4] *Zement Protokoll*, 1906, p. 149.
[5] *Koll. Chem. Beihefte, Vol.* 1. 1910.
[6] *Koll. Z.*, Vol. 34, p. 117, 1924.
[7] Bureau of Standards Portland Cement Fellowship, Paper 11.

of mortar are different from those of cement in excess water; that is exactly what I have always maintained.[8]

As regards "viscosity," Mr. Tippmann obviously confuses the "pasty consistency" of the entire system and the "internal friction" of the liquid phase. He emphasises the "high viscosity" of "fresh normal mortar." Fresh mortar is a heterogeneous system with only one liquid phase, and to this phase alone can the term "viscosity" be applied; the viscosity of this liquid, which is essentially lime water, is not greatly different from that of water.

Mr. Tippmann's view that the pressure due to the growing $Ca(OH)_2$ crystals greatly dehydrates and compresses the silica gel cannot bear serious examination. What becomes of the water pressed from the gel? It must either form a new liquid phase and again liquefy the whole system, or it must exude, or even "at high pressure" spurt from the hardened mass.

(3) "The needle crystals formed in specimens gauged with excess of water consist of $Ca(OH)_2$; they are not formed in mortars of normal consistency."

The occurrence of $Ca(OH)_2$ in fine needles has been observed only by Mr. Tippmann. I have failed to substantiate it. Even if it were found that $Ca(OH)_2$ occasionally formed needles, it is by no means certain that the needles obtained by Keisermann and Blumenthal from cement and large excess of water are $Ca(OH)_2$. I consider these workers proved that their needles contained silica.

(4) "Calcium hydrosilicates are not found in hardened cement, in either crystalloid or colloidal form."

This is merely the reverse of (1), and the same remarks apply.

(5) "The whole of the hydrolytically formed $Ca(OH)_2$ in cement mortars exists in the crystalline modification. These crystals are not the hexagonal plates and rods obtained with excess of water, but consist of irregular lamellæ of shapes best adapted for filling the available space."

(6) "Crystalline or crystallisable $Ca(OH)_2$ cannot be considered to be the cause of lime expansion. Hydrolytically formed $Ca(OH)_2$ always possesses the power to crystallise without a promoting agent. Amorphous $Ca(OH)_2$ can only crystallise in the presence of a promoting agent. It is the cause of lime expansion, and is formed only in the later stages of hardening of cements containing free lime, when the promoter of crystallisation (gypsum) has no further effect."

Statements (5) and (6) depend on the assumption of two "modifications" of $Ca(OH)_2$, *viz.*, "crystalline or crystallisable" and "amorphous or "amorphous-colloidal." What, however, can be meant by a "crystallisable" modification? The term can, perhaps, be applied to a solution or an amorphous structure, but it cannot be synonymous with "crystalline," since a crystalline substance has already lost its capacity for crystallisation. In the same way the words "amorphous" and "colloidal" have different meanings, and it gives rise to confusion if they are used together as having the same meaning. "Amorphous" indicates the state of a material as opposed to crystalline, while "colloidal" indicates the degree of dispersion of two phases in each other, in contrast to true solutions and coarse mechanical mixtures. This distinction is important as regards my standpoint in the theory of hardening. When I base my views on the colloidal conception it means merely that I reject the assumption of a coarsely mechanical interweaving of crystals. It does not follow that the colloidal material formed in the solid phase may not have a fine crystalline structure. I have always emphasised that thin sections of even young test-pieces show diffused light between crossed nicols, *i.e.*, there may be fine crystalline structure.[8]

[8] *Zementprotokoll*, 1922, p. 108.

I have no previous knowledge of an amorphous modification of calcium hydroxide of sp. gr. 2.08, additional to the crystalline hydrate of sp. gr. 2.23. It is possible, however, that Mr. Tippmann has discovered such a new modification. Even if this were established, his results would appear to me surprising, and I have therefore asked my assistant, Dr. Thilo, to check his microscopic observations and Count Czernin to check the chemical work.

Mr. Tippmann describes the following four methods of preparing crystalline and amorphous calcium hydrate:

(i) On treating Portland cement with excess water, $Ca(OH)_2$ crystals are gradually deposited on the walls of the flask.

(ii) Slaking CaO with water gives exclusively amorphous, partially colloidal hydrate, and no crystallisation occurs even after many years.

(iii) Slaking CaO with gypsum solution gives crystalline hydrate in hexagonal plates.

(iv) Slaking CaO with very dilute gypsum solution gives fine needles of crystalline hydrate.

These observations are mostly easily explained from the experimental conditions. As regards (i) we are dealing with a very slow reaction. The constituents of the clinker dissolve in the mixing water, with which they react to form $Ca(OH)_2$. The $Ca(OH)_2$ gradually formed in solution ultimately attains supersaturation, so that slow crystallisation ensues.

In (ii) we have a very intensive reaction. A high degree of supersaturation rapidly results and prevents the formation of well-defined crystals. Under these conditions colloidal systems are readily formed, the disperse phase being first formed in the unstable form and passing later—often very slowly—into the stable form.

In (iii) the dissolved salt and its ions greatly modify the stability conditions of the disperse phase, and it is not surprising that the tendency to crystal formation is increased.

It is, however, remarkable, and not easy to understand, that slaking CaO with water should give exclusively amorphous hydrate and that this should remain completely stable over a number of years. It is also remarkable that slaking with very dilute gypsum water should give crystalline hydrate consisting of fine needles.

In our own experiments we used CaO obtained by igniting pure precipitated $CaCO_3$ at 1,150 deg. C. This was treated under the most varied conditions with water, saturated gypsum water, and 1/10 saturated gypsum water. Slaking experiments with small quantities of liquid were made, and the lime pastes were either allowed to age as formed or were mixed with excess water and agitated in a shaking machine, sometimes for weeks. In other tests the CaO was rapidly slaked by a large excess of liquid. The lime slaked with water or 1/10 gypsum water gave a light voluminous product. With saturated gypsum water the product was heavier and settled comparatively quickly.

The products were microscopically examined, both as formed and after ageing. No basic difference was found between any of them. The fresh precipitate was always fine, and no well-defined crystals could be detected. Between crossed nicols there were, however, numerous luminous points, so that at least a considerable proportion was of a crystalline nature. The preparations obtained with a saturated gypsum were only different in so far as they were generally of coarser structure. Apparently on slaking, the vigorously precipitated hydrate is formed of colloidal dimensions, but the colloidal particles possess crystalline structure. It would follow that this fine structure should become coarser with time, but no sign of this could be detected in 20 days, and the change is probably very slow, as indicated by Mr. Tippmann's observations. In no case was the formation of fine needles observed.

The following experiment was made to test Mr. Tippmann's view that crystalline $Ca(OH)_2$ cannot be formed from CaO and water directly, but must be formed by hydrolysis or through the action of catalysts. CaO was slaked in one case with water and in another with saturated gypsum water. When the solid had settled the supernatant liquids were transferred to flasks and evaporated *in vacuo* over calcium chloride. After some weeks, when the greater part of the liquid had evaporated, the material deposited on the walls of the flask was examined microscopically. In both cases it consisted of small crystals of calcium hydrate of imperfect shape, frequently only spherolithic. In the one case these were, of course, accompanied by gypsum crystals. Thus by slaking CaO with pure water —which, according to Mr. Tippmann, can never give the "crystallisable" modification of $Ca(OH)_2$—we have obtained lime water which crystallises on evaporation in exactly the same way as the gypsum-lime water obtained by slaking with gypsum solution.

Finally we investigated the volume changes occurring on slaking lime with pure water and gypsum water respectively. According to Mr. Tippmann, the former should give amorphous hydrate of sp. gr. 2.08, and the latter crystalline hydrate of sp. gr. 2.23. It follows that in the Kühl flask experiment the former must give an expansion and the latter a contraction. Experiment gave a contraction in both cases, and the two were numerically equal. This is in complete agreement with my observations published in *Tonindustrie Zeitung* (p. 1333) in 1912.

The above results bring Mr. Tippmann's observations into agreement with our previous views on the properties of calcium hydrate. The only new point remaining—and this is neither surprising nor in conflict with the old ideas—is that the colloidal system obtained on slaking lime with water is relatively very stable (is this really new in the light of experience with builders' lime putty?), and that the presence of gypsum during hydrate formation reduces the degree of dispersion. This, however, does not justify us in rejecting our theory of hydraulic hardening to replace it with Mr. Tippmann's theory. Indeed, there is no need to make any appreciable change in our theory.

(7) "The hardening of Portland cement depends upon the ideal co-operation of colloidal silica and crystalline $Ca(OH)_2$, the latter being the most plentiful and most important ingredient of hardened Portland cement. The $Ca(OH)_2$ is the basis of the cementitious property of cement and is thus the cause of hardening."

That the hardening of Portland cement depends on the ideal co-operation of several reactions is a view with which I generally agree,[9] but I consider that the newly-formed substances first appear in colloidal form and only become coarsely-crystalline on ageing. There is no need to modify this opinion as a result of Mr. Tippmann's microscopic work, which will be dealt with under (8), since my arguments on Statement (1) show the view that "$Ca(OH)_2$ is the basis of the cementitious property of cement" cannot be upheld. The fact that a hydrosilicate of calcium is the most important constituent of hardened cement has not been affected by Mr. Tippmann's observations.

(8) "A microscopic process is described which enables the phenomena of the hardening of normal mortars to be followed."

Mr. Tippmann uses obliquely-incident parallel light (see his Fig. 6), which he splits up by the different effects of crystals and colloids. The matter is not, however, as simple as he indicates, since the crystals do not all lie with their reflecting surfaces parallel to the object glass, but have all orientations. Thus, of the many rays reflected from crystals, some will be reflected along the axis of the microscope. However, such cases are exceptional, so that the crystals

[9] *Zementprotokoll*, 1912, p. 318; *Zement*, Vol. 12, p. 155, 1923.

will generally appear dark, while the fine disperse masses will scatter the light, and the field will be illuminated. It may thus be admitted, and my experiments have confirmed, that Mr. Tippmann's microscopic method has its advantages, but nevertheless I have not been able to observe the phenomena in hardened cement which he describes. Even a freshly-mixed cement, *i.e.*, one which cannot yet contain new compounds, shows by this method the presence of numerous coarse crystals embedded in a fairly continuous, highly-disperse groundmass. We must therefore either assume with him that even a few minutes after mixing such vigorous reaction has occurred that the mass already consists almost entirely of silica gel and $Ca(OH)_2$ crystals, or, what is actually the case, that the crystals observed are alite, while the luminous mass consists partly of the cement flour floating in water and possibly also of coarser cement grains of very fine structure.

It is particularly important that this original appearance is not appreciably changed even after four weeks. Certainly no increased darkening of the field due to growth of the crystal mass can be detected. It rather seems that the contrast is less well defined with lapse of time, which may be attributed to decomposition of the larger alite crystals.

In addition to using Mr. Tippmann's method, Dr. Thilo has studied mixed cement by transmitted light. If a cement is very finely ground and is mixed with just a little more water than in standard practice, by rubbing the object glass on the microscopic slide a layer can be obtained sufficiently thin to transmit light. This method proved much more fertile than Mr. Tippmann's. It was found on examination by polarised light that the initially brightly-illuminated crystals gradually disappeared and that the diffusely illuminated groundmass spread over them. No formation of new crystals could be detected either by polarised or normal light.

It is thus shown that Mr. Tippmann's microscopic method can find use as an amplification of other optical methods, but that his deductions appear to rest on fallacies.

(9) "Gypsum expansion is due to over-abundant crystallisation of $Ca(OH)_2$, as a result of which the available quantity of silica gel is inadequate. On the other hand, it is possible to convert a cement subject to lime expansion into a sound cement by the addition of gypsum, which acts by transforming the amorphous $Ca(OH)_2$ into the crystalline modification. In practice this is only possible to a limited extent, for an excess of crystalline $Ca(OH)_2$ may result."

We have checked the observations which led Mr. Tippmann to his conclusions regarding lime and gypsum expansion. He says that "gypsum solution dissolves much more $Ca(OH)_2$ than can water" (p. 1124). Count Czernin has tested the solubility of gypsum in lime water, of lime in gypsum water, and of lime and gypsum in water, by shaking for some days at air temperature. The results showed, as would be anticipated from theory, that gypsum and lime reciprocally somewhat lower the solubility of the other substance. Thus, the assumption appears to be false and the opposite true.

Mr. Tippmann seems to have been led to this assumption by the fact that some time after mixing cement the mixing water contains more lime than its solubility warrants. But this is just as true in the absence of gypsum. This supersaturation is due to the hydration of the cement; naturally, supersaturation must arise before calcium hydrate can be separated. It cannot be accepted that the mixing water, immediately after mixing, is "not as yet saturated with $Ca(OH)_2$." Even when cement is gauged with an abundance of water we cannot work sufficiently rapidly to separate the water before it is saturated with lime.

Mr. Tippman found microscopically that a Portland cement containing 72

per cent. CaO, which was extremely unsound without gypsum, could be made sound by an addition of 3 per cent. of gypsum. It is well known that expansion can be reduced in many ways. Among these means are very fine grinding, and dilution by expansion-free additions, such as blast-furnace slag; also the addition of chemicals which increase the strength, such as gypsum and calcium chloride. This is because expansion manifests itself the more feebly as the cohesion of the cement is stronger.

Admitting that gypsum improves unsound cement, it is impossible that a cement containing 72 per cent. CaO can be completely corrected by gypsum. It would appear that Mr. Tippman's microscopic test is unsuited to the purpose of testing expansion.

Therefore, statement (9) must be rejected. Not only does it seem impossible to confirm the experimental basis, but the existence of the various forms of calcium hydrate upon which it depends cannot be accepted.

To summarise, in no case do Mr. Tippmann's experiments appear to justify the nine statements in which he expresses his results, and it seems that he has failed to shake in the least degree the older well-established theory.

BY Mr. F. F. TIPPMANN.

In Professor Kühl's criticism of my paper he introduces many superfluities, and his check experiments are not entirely appropriate to my work, which is based on very comprehensive data. I maintain that my results will be unconditionally confirmed by all correctly carried out checks. Like Professor Kühl, I will deal with my reply under the nine summarising statements of my original paper.

(1) I must repeat that under normal conditions (*i.e.*, conditions normal to the practical working of cement) it has not been possible to prepare a well-defined calcium hydrosilicate, and this probably never will be possible. The theory that "calcium hydrosilicate is formed on hydration of Portland cement" is quite as arbitrary as my own theory of the formation of free silica and crystalline calcium hydrate. There is no conclusive evidence for hydrosilicate formation, and my own theory offers a better explanation of hardening.

With regard to the natural hydrosilicates (okenite, etc.) instanced by Professor Kühl, their conditions of formation have nothing in common with the hardening of cement; they require high temperatures and pressures. This has been admitted by Professor Kühl in the case of hillebrandite.[1] It is interesting that amorphous calcium hydrosilicate, such as is assumed in set cement, is not found in nature. On the other hand, hardened silica gel containing crystalline hydrates, in analogy to my theory, are found.

When Professor Kühl says that if complete hydrolysis of calcium silicates by water actually took place "hydrosilicate could not be formed from lime and silica hydrates," this is exactly what I maintain—that hydrosilicate is not formed. When he refers to the work of Le Chatelier, Jordis and Kanter, etc., I must point out that these workers did not obtain calcium hydrosilicate under normal conditions; I presume that Professor Kühl here refers to true chemical compounds; he refers to the work of these authors as follows: (1) "These investigations have attained no importance in the technical aspect of mortars since they were carried out under such different conditions."

I presume that Professor Kühl agrees that an adsorption compound is not a stoichiometric—*i.e.*, chemical—compound, but a mixture of the free components held together solely by physical forces (adsorption, capillarity, or surface force). Before such compounds can be formed from calcium silicates, complete

[1] Foreword to Klasse's paper, *Zement*, 1928, Nos. 1 and 2.

hydrolysis must occur. Professor Kühl will also, no doubt, admit that Klasse[1] did not work under such conditions as to justify applying his results directly to the hardening of cement.

Thus, my contention, that no calcium hydrosilicate has been prepared that can or must be considered to exist in cement, is fully upheld, and statement (1) of my original paper must be accepted. The artificial hydrosilicates are obtained with great difficulty and under most abnormal conditions. Even so, their existence is doubtful, and they are very readily hydrolysed. Even if they were formed at all in the hydrolysis of clinker, they would be rapidly decomposed to free silica and calcium hydrate.

(2) It is difficult to see why Professor Kühl objects to the statement that normal mortar has high viscosity. His digression as to the term "viscosity" I consider superfluous. It is quite customary to speak of, and to measure, the viscosity of a raw material slurry, and W. Ostwald, as well as many other workers, has made viscosity measurements on suspensions. We can therefore speak of the "viscosity" of a heterogeneous system, and that of cement mortar is undoubtedly very high compared with water.

With reference to Professor Kühl's objection to the "pressure due to the growing $Ca(OH)_2$ crystals," I would refer him to Liesegang's "Formation of gels through crystals."[2] My Fig. 12 clearly demonstrates this. As regards "the water pressed from the gel," my work clearly shows that in the ideal case of hardening—which can hardly be attained in practice—the whole of the mixing water is combined to form the calcium hydrate crystals. In intermediate cases it is shared between these crystals and the silica gel. It is known that water opal (pure hard silica gel), with a Moh hardness value 5-6, still contains 5-12 per cent. water. If the silica gel of hardened cement contains 16 per cent. water it can possess a crushing strength of 13,000-14,000 lb. per sq. in. Michaelis[3] took an extremely finely ground Portland cement and dried it over sulphuric acid after setting. He then found a loss on ignition of 20-21 per cent., a quantity corresponding to the lime content of the cement as monohydrate. This is the ideal case of hardening. Krauss[4] carried out thermal dehydration experiments on hardened tricalcium silicate and found that it was completely hydrolysed.

(3) Many other workers besides myself have obtained calcium hydrate in the form of fine needles. Indeed, almost all crystalline substances form needles under certain conditions. If cement particles are moistened with water on a slide and covered with a slip, these crystals will be obtained. They may also be obtained from pure lime burnt at 1,025 deg. C. by moistening with a drop of dilute gypsum water. I consider Keisermann and Blumenthal did not definitely prove that their needles obtained from cement consisted of calcium hydrosilicate.

In general, the conditions for the formation of needle crystals do not exist in dense mortar. Even calcium sulphoaluminate cannot form needles in dense mortar; it can only be formed as needles in pores and cracks.

(4) This statement is dealt with under (1).

(5) and (6) I agree that the term "crystallisable" is possibly not a very happy one. It was chosen for want of a better, and is clearly defined in my original paper, so that it cannot lead to confusion. The following data on "an amorphous modification of calcium hydroxide of sp. gr. 2.08" have been published: Chemiker Kalender (1929), amorphous 2.08, cryst. 2.23; Kohlschütter and Walther, amorphous 2.078, cryst. 2.239; Goslich and Hart (1923) give 2.078, but do not state whether they are dealing with amorphous or cryst. $Ca(OH)_2$.

[2] *Kolloid Zeit.*, Vol. 7, p. 96, 1910.
[3] *Zement Protokoll*, 1899, p. 159.
[4] *Tonind. Zeit.*, 1929, p. 1333.

I have redetermined this constant and again found the values amorphous 2.08, cryst. 2.23.

Professor Kühl, in the Protokoll of 1912, says: "I have made these calculations on the basis of values found in the literature, and found that the combination of burnt lime and water proceeds . . . with contraction." Although the value of the sp. gr. of the hydrate is not given, the result shows that he used the higher sp. gr. of the cryst. hydrate. I do not profess to have discovered a new modification of calcium hydrate, but consider that it would be very desirable to clear up the question definitely.

Let us discuss next the methods of preparing the various forms of calcium hydrate:

(i) The following explanation of the formation of calcium hydrate crystals from cement and excess water is, I think, preferable to that of Professor Kühl: $Ca(OH)_2$ passes into solution as a result of the hydrolysis of the clinker compounds. The Ca-ion concentration is thus increased until $Ca(OH)_2$ crystals separate. I have specimens of fine cement which have been in contact with excess water for six years. They are greatly swollen, and the $Ca(OH)_2$ formed appears entirely crystalline to the naked eye.

(ii) Slaking burnt lime with water never produces crystals so long as the liquid is in contact with the solid phase, even after standing several years. The solution must, however, be saturated and even supersaturated with $Ca(OH)_2$, yet crystals do not separate as in the case of cement. The amorphous hydrate thus appears to be a stable modification with no tendency of itself to pass into the crystalline state. Professor Kühl's experiment in which he separated the liquid from the solid phase and evaporated *in vacuo* was superfluous; I emphasised in my paper the necessity of the presence of the solid phase. Professor Kühl attributes everything to the "very intensive reaction." But lime burnt at 1,600-1,800 deg. C. reacts extremely slowly with water, yet even under these conditions only amorphous hydrate is formed.

(iii) Coarse grains of CaO (5-8 mm. diameter) in contact with saturated gypsum solution did not react vigorously. After shaking several times in twelve hours the grains of lime retained their shape. After twenty-four hours the mass was cemented together by $Ca(OH)_2$ crystals, some of which were 5 mm. in size. This result was quite different from my check experiment with 5-8 mm. grains and water, in which after ten minutes the grains of lime had formed a very fine amorphous suspension. Gypsum is thus a promoter of crystallisation in the amorphous hydrate, *i.e.*, a catalyst.

(iv) I have already dealt with the production of $Ca(OH)_2$ in needle crystals. A week's shaking in a flask is hardly likely to give these delicate crystals. In the case of preparations of cement in excess water, no needles are to be found where the cement grains are densely congregated; they are to be found generally around isolated cement grains, and any check experiment must be made in this sense.

(7) That "a hydrosilicate of calcium is the most important constituent of hardened cement" is not a "fact," but merely an assumption.

(8) With regard to the microscopic observations, I have confirmed my results in hundreds of cases over recent years. If Professor Kühl will continue the work, I am convinced that he will obtain the same results. It can hardly be true that a diffusely illuminated groundmass is obtained both by my process and in transmitted polarised light. Further, my work in no way shows that "even a few minutes after mixing, such vigorous action has occurred that the mass already consists almost entirely of silica gel and $Ca(OH)_2$ crystals." On the contrary, I have accurately followed the gradual development of the phenomena.

Again, I cannot conceive that coarse alite crystals are present in the specimens in the case of a modern finely ground cement. I admit that the contrast may be less well defined with lapse of time, since hardened cement is lighter in colour. As regards the diffuse illumination of the groundmass in transmitted polarised light, this may be attributed to many layers of $Ca(OH)_2$ crystals of all possible orientations; complete extinction of light is thus impossible whatever the position of the specimen. On rotating the specimen, however, I always find that certain areas defined by straight lines become alternately darker and lighter. Check experiments will show that my views do not rest on fallacies.

(9) It is possible that I may be wrong in assuming that "gypsum solution is able to dissolve much more $Ca(OH)_2$ than water." There is evidence for this in the literature, but I have not checked it experimentally. In any case gypsum is undoubtedly a good promoter of crystallisation of $Ca(OH)_2$, so that my main statement is true. In 1923, Professor Kühl[5] found that gypsum is the best material for promoting hydraulicity in granulated blast-furnace slag; this agrees with my thesis that the gypsum causes the favourable crystallisation of the $Ca(OH)_2$ formed from the slag.

My statement that "the mixing water after mixing is not as yet saturated with $Ca(OH)_2$" is an error; the word "saturated" should read "supersaturated." The instance of correcting the expansion of a cement of 72 per cent. lime content by means of gypsum naturally only refers to the microscopic test; in practice 3 per cent. gypsum would obviously be inadequate. The experiment shows, however, that in general correction of expansion results from the crystallisation of the amorphous $Ca(OH)_2$.

BY PROFESSOR KÜHL.

(1) When I said I had no previous knowledge of an amorphous modification of calcium hydrate of sp. gr. 2.08, I expressed myself somewhat inaccurately. I do not oppose the existence of amorphous hydrate, but merely question the existence of a definite modification of sp. gr. 2.08. A definite modification of sp. gr. 2.08 cannot be formed on slaking CaO, for the reason that slaking takes place with contraction, not with expansion. With regard to the numerical data given by Mr. Tippmann, the first reference is unauthoritative, while the other two may both be traced back to Filhol so long ago as 1847. It is quite possible that Filhol's hydrate had absorbed water vapour and therefore gave a low sp. gr.

(2) Dorsch, as well as myself, has failed to confirm Mr. Tippmann's results.

(3) In conclusion, all that is necessary has been said in my original reply, and agreement is obviously impossible. I will therefore content myself with repeating the following statement: The generally accepted fact that calcium hydrate and silica in contact with saturated lime water give a calcium hydrosilicate makes it impossible that the calcium silicates of Portland cement should be hydrolysed in contact with saturated lime water to give free calcium hydrate and free silica. This is conclusive, and is in no way shaken by the circumstance that the constitution of the calcium hydrosilicate is as yet not accurately known.

BY DR. K. E. DORSCH.

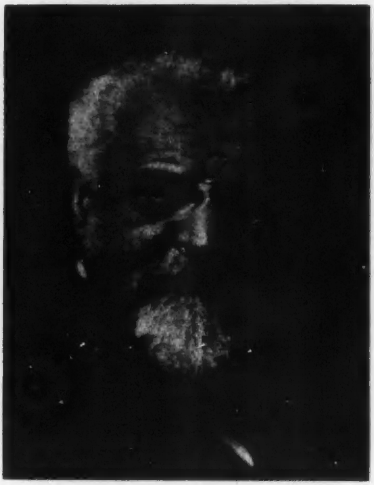
A brief reply to Mr. Tippmann's article by K. E. Dorsch appeared in a recent number of "Zement." He states that he has repeated Mr. Tippmann's experiments in slaking burnt lime with water and gypsum solutions, but has been unable to reproduce the same results. He finds that the only difference between the effect of pure water and gypsum solution is that with the latter the particle size of the amorphous hydrate formed appears to be somewhat larger. Under the polarisation microscope the preparations appear luminous, so that the solid phases must possess in part a microcrystalline structure.

[5] *Zement*, Vol. 12, p. 320, 1923.

Fifty Years in the Cement Industry.

THE firm of F. L. Smidth and Co., whose headquarters are in Copenhagen, celebrated its fiftieth anniversary on January 2 last. During this period the business has developed world-wide interests in the supply of cement-making plant.

The business was founded by Mr. F. L. Smidth in 1882, and very soon after he was joined by two other engineers—Mr. Poul Larsen and Mr. Alexander Foss. The firm at first undertook consulting engineering work, and specialised in brickmaking plants. In 1888 they designed their first cement works, and soon after they took up the manufacture of cement-making machinery.



Mr. Poul Larsen.

AN ORIGINAL PARTNER AND PRESENT CHAIRMAN OF F. L. SMIDTH AND CO. AND ASSOCIATED COMPANIES.

The first tubemill was put on the market by the firm in 1893, and since then this machine has been used in hundreds of cement works and in the mining industry throughout the world. The first cement works built by the company were erected in Sweden and Denmark.

A branch office was established in London in 1890, only two years after the first cement works had been built. In 1893 offices were opened in Paris and St. Petersburg (now Leningrad), and in 1895 a branch was established in New York.

From the beginning the technical as well as the commercial side of the concern has been carried on by engineers. An active interest was taken in cement manufacture, and this gave the firm an opportunity to acquire first-hand experience in the technique of cement making and to train a staff of chemical, mechanical, electrical, and civil engineers.

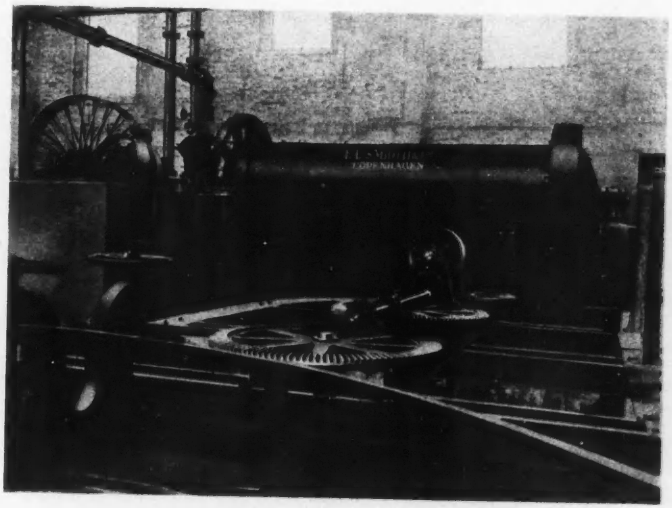


Fig. 1.—An Early Tubemill, about 2 ft. diameter by 12 ft. long.

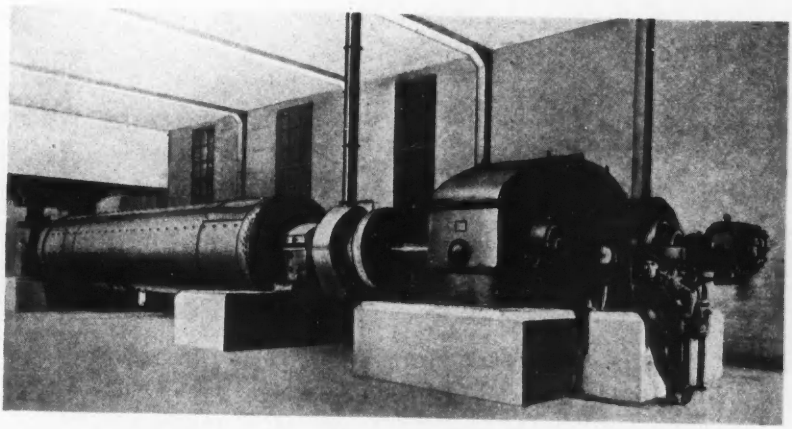


Fig. 2.—A Modern Grinding Mill, about 8ft. diameter by 50 ft. long.

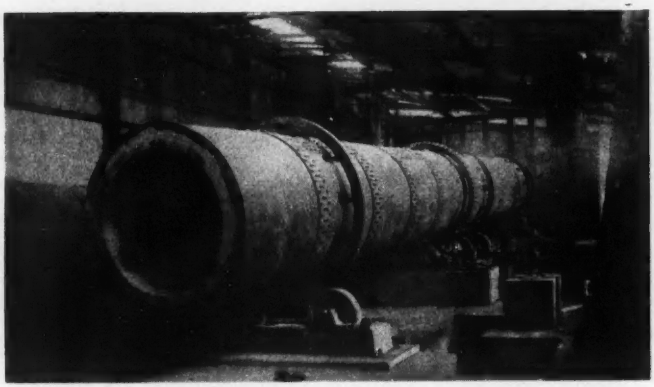


Fig. 3.—The First "F. L. Smidth" Kiln.

An idea of the progress made in the cement industry is given by the accompanying illustrations. Fig. 1 shows one of the first tubemills. The first tubemill built was about 2 ft. in diameter and 12 ft. long, and required 6 h.p. to drive it. The latest type of grinding mill made by the firm is nearly 8ft. in diameter, about 50ft. long, and requires 1,400 h.p. The first rotary kilns made by the firm were about 50ft. long, and had a capacity of 1¼ tons per hour. The firm is to-day making kilns nearly 500 ft. long with a capacity of about 20 tons per hour. Fig. 3 shows the first kiln erected by the company in Aalborg, and Fig. 4 shows one of the latest type of kilns. Up to the end of 1929 the firm had supplied no fewer than forty-four rotary kilns in this country alone, while

Fig. 4.—A Modern Kiln.

forty-one "Unidan" mills, with a total capacity of 4,300,000 tons a year, had been installed in England. In addition to tubemills and kilns the firm have been responsible for developing numerous machines well known in the cement industry for the conveying and automatic packing of materials, and they have also developed new processes and plant used in the mining and metallurgical industries.

The office in Copenhagen employs a technical and clerical staff of more than 500 people, and besides offices in London the firm has branch offices in New York, China, France, Germany, Italy, and Japan. The policy of the firm is to manufacture their machinery in most of the countries where they do business, and they have either their own engineering works or working agreements with other firms in ten different countries in Europe, as well as in the U.S.A., Australia, and Japan.

The firm's interest in the cement industry is shown by the fact that they are the principal shareholders in thirteen cement works in Denmark, England, Egypt, Esthonia, Germany, Norway, and Portugal; these works have a total capacity of about 1¾ million tons per annum.

Of the original partners of the firm, Mr. F. L. Smidth died in 1899 and Mr. Alexander Foss in 1925. The third, and only surviving, partner, Mr. Poul Larsen, is chairman of all the companies and undertakings associated with F. L. Smidth and Co. He takes a very active interest not only in the engineering firm but also in the various cement companies controlled by and associated with F. L. Smidth and Co., as well as numerous other undertakings.

Cement Companies' Dividends.

Belgium.—The S.A. des Ciments Portland Liègeois, Haccourt, is maintaining its dividend of 15 fr. The net profit for the year was 3,324,946 fr. (£18,999) compared with 3,492,322 fr. (£19,956) for the year 1929-30. The S.A. des Cements Meuse-Brabant is also maintaining a 20 fr. dividend with a net profit of 1,300,000 fr. (£7,428). The net profit for 1929-30 was 1,079,654 fr. (£6,169). Cimenterie et Briqueterie de Tilleur S.A. has declared a dividend "on capital" of 10 per cent. for 1930. The trading profit was 551,508 fr. (£3,151). The S.A. Niel-on-Rupel (holding company for the C.B.R. group) has declared a net profit of 923,408 fr. (£5,276) compared with 7,727,000 fr. (£44,154) for 1929.

(Note: All conversions are made at par.)

BINDING CASES

for "Cement & Cement Manufacture."

Strong binding cases for the 1931 volume of "Cement & Cement Manufacture" are now ready, price 3*s.* 6*d.* (by post, 3*s.* 9*d.*) each. These cases are cloth covered, with the title of the journal and the date of the volume blocked in gold on the side and spine. If desired, we will undertake the work of binding at an inclusive charge of 6*s.* plus 6*d.* postage; in this case the twelve numbers should be sent post paid to Concrete Publications, Ltd., 20 Dartmouth Street, London, S.W.1. For the information of those who may wish us to complete their sets, all the 1931 numbers are in print and can be supplied.

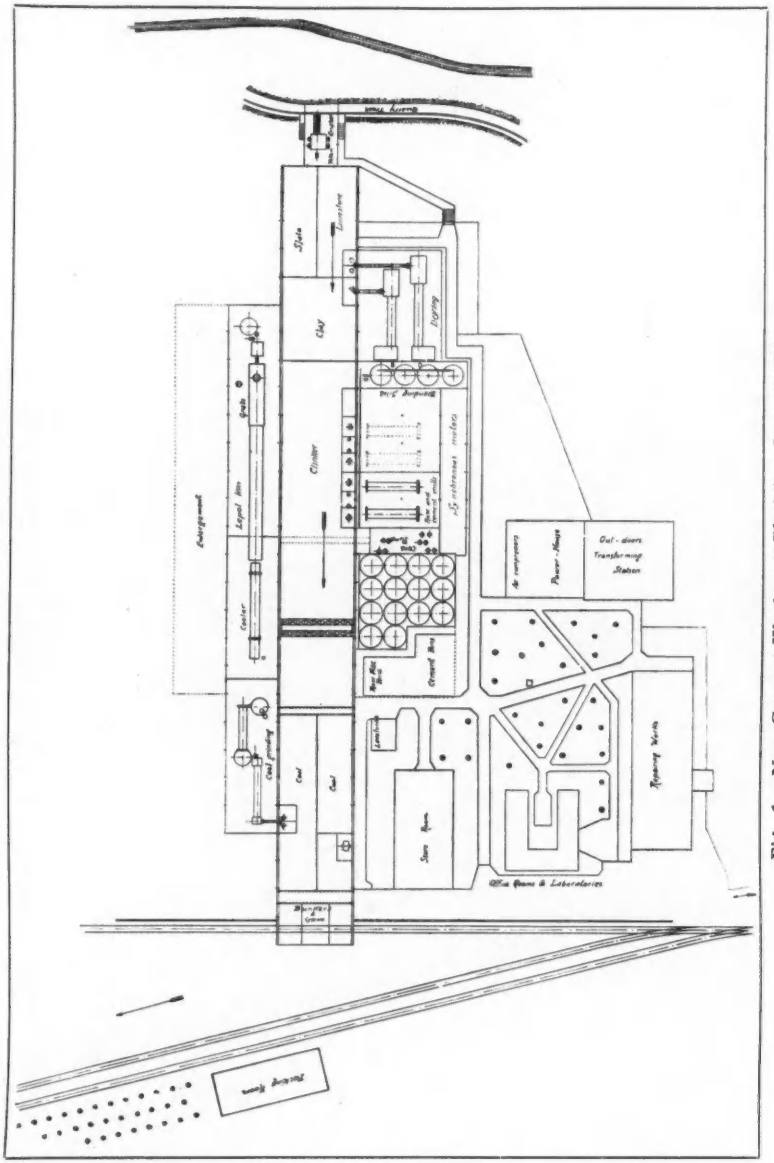


Fig. 1.—New Cement Works at Córdoba : Lay-out Plan.

New Cement Works at Córdoba, Spain.

By A. MARGARIT.

A NEW Portland cement works belonging to the Asland Córdoba S.A. (an affiliated company of the Compañia General de Asfaltos y Portland Asland, Barcelona) started operations in April, 1931. The works, which have an annual output capacity of 80,000 tons, are built for manufacture by the dry process and use the "Lepol" burning system, and "Cera" compressed-air pumps for the transport of pulverised materials.

Site.—The works are about half a mile from the city of Córdoba, and are connected to it by the Madrid-Seville Railway and the road from Córdoba to Almaden. An important market is open to cement in the Guadalquivir basin, where extensive hydraulic works have been planned.

Raw Materials.—Two quarries are worked at present, one about a quarter mile from the factory, and the other 1¼ miles away. The nearer has strata of Cambrian formation, with alternate layers of limestone and shales; although the Cambrian limestones possess, in some places, a high calcium carbonate

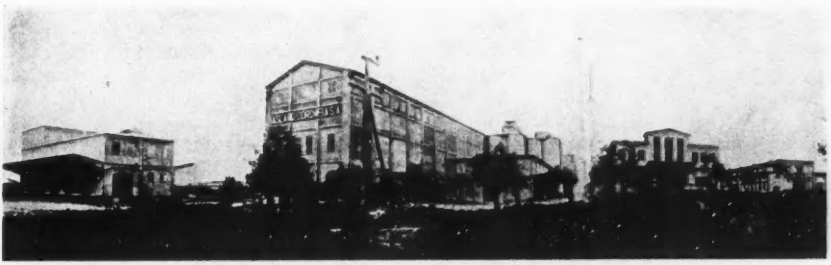


Fig. 2.—New Cement Works at Córdoba.

content, the farther quarry has deposits of excellent oligocene limestone to balance the former material. A 2-ft. gauge railway has been installed in the first quarry, and trucks are used for transport; stone from the second quarry is conveyed by motor trucks. Quarrying in both cases is done by pneumatic drills and blasting. The compressor is driven by a motor fed from the mill through a high-voltage line and a transformer.

Preliminary Crushing and Drying.—On reaching the mill the stone is reduced to ¾ in. in a "Titan" crusher, built by the Miag A.G., Braunschweig, Germany. The stone is then conveyed to two large bins situated in a large building, about 650 ft. long by 66 ft. wide, with an average height of 80 ft. A "Krupp" travelling crane, with clamshell buckets, traverses the length of the building and serves for the transport of both raw materials and of clinker, coal and gypsum. The stone is transported by the crane to the hoppers, whence it is fed to travelling belts, and is thus conveyed to rotary driers heated with pulverised coal. From these the raw materials pass to mixing silos, each having at the lower end two "Balan" automatic weighing machines, which weigh the materials before passing to the mill bins.

Grinding.—Two mills have been erected which can grind either raw materials or clinker. Each of these mills is at present used for one material, but, if necessary, the feed and discharge of the mills can be easily altered. Both mills

are of the "Solo" three-compartment type, manufactured by Polysius, and are 7 ft. 4 in. in diameter by 43 ft. long. Efficient dust-collecting filters are attached. The total load of grinding media is 43 tons 6 cwt. in the raw mill, and 47 tons 5 cwt. in the cement mill. With this charge the raw mill can produce an average of seventeen tons per hour, with a power consumption of 575 H.P. The cement mill produces an average of about fourteen tons per hour, also with a power consumption of 575 H.P.

The raw meal and the ground cement are drawn from the mills to their respective silos by two "Cera" pneumatic pumps. A circulating pump removes the pulverised raw material at the bottom of the silos, and distributes it again among four of these silos. This process causes great evenness of mixing of the raw meal, so that any fluctuations that may exist in the quality of the ground material are completely cancelled, and a raw meal is obtained of almost perfect uniformity.

The following analysis is representative of the chemical composition of the raw meal used at Córdoba:

SiO_2	14.80 per cent.
Al_2O_3	3.94 ,,
Fe_2O_3	1.91 ,,
CaO	42.55 ,,
MgO	1.78 ,,
Ignition loss	35.14 ,,
Lime ratio	2.13 ,,

The Kiln.—The burning process is effected in a kiln of the "Lepol" type, built by G. Polysius A.G., Dessau. The raw meal is pumped to the kiln hopper, from which it is fed to a granulating drum to be prepared for the burning process. When granulated it enters the first part of the kiln, where it undergoes the first thermal process on the moving grate, being desiccated and to a large extent decarbonated. It then enters the rotary zone of the kiln, where the clinkering process is completed.

The clinker travels through a rotary cooler in which it yields a large part of its heat to the secondary air feeding the kiln. The waste gases are sucked through the moving grate, which is loaded with a uniform layer of material, by a 220 H.P. electric fan. However, with a power consumption of 175 H.P. a suction equivalent to 6 to 7 in. W.G. can be obtained. The gases reach the discharge stack at a temperature of about 250 deg. F.

In the severe tests to which it was submitted, the kiln fulfilled the guarantees given by the constructing firm; it scarcely exceeded 100,000 kilocalories per 100 kilos. of clinker produced (180,000 B.Th.U. per 100 lb.), never exceeding 105,000 kilocalories (189,000 B.Th.U. per 100 lb.). The fuel economy thus obtained is really important.

The effective portion of the "Lepol" moving grate, *i.e.*, the part occupied by the material being burned, is 10 ft. by 33 ft. The rotary kiln following this grate, where the burning process is finished, is 10 ft. 6 in. in diameter by 112 ft. long. The rotary cooler is 7 ft. 3 in. wide by 80 ft. long. The output guaranteed and obtained is 240 tons per 24 hours.

Fuel.—Pulverised coal is used as fuel. A mixture of anthracite and bituminous coal is prepared, both kinds of coal coming from mines situated not far from Córdoba. This mixture has a calorific value of 12,240 B.Th.U. per lb., and contains 20 per cent. volatile matter. Coal reaches the works by the railway, and is unloaded from the wagons into the coal bins 1 and 2 (bin No. 3 receives

gypsum). Then the travelling crane takes it to the storage bins, and to hoppers 1 and 2. From these points it is fed to the rotary drier, and thence to the mill. Pulverised coal is collected in a bin, whence another "Cera" pump distributes it at the different points where it is to be consumed, namely, the kiln, the raw material driers and the coal drier.

Packing Department.—Another compressed-air pump carries the ground cement from the cement silos to the packing building. A two-spout "Bates" machine fills the jute sacks, of valve type, in which cement is shipped either by railway or in motor trucks for local delivery.

Power Transmission.—The system adopted has been that of individual motors directly coupled, reducing gears being used whenever the speed of the machine requires it. The contractors for electrical material were Brown Boveri, Baden; Luth & Roséns Elektriska Aktiebolag, of Stockholm; and the Sociedad Construcciones Electromecánicas, of Córdoba (Spain). For driving the "Solo" mills high speed motors of the asynchronous-synchronised type have been chosen, with reducing gears.

Power.—The current supplied to the works is three-phase, 50-cycle, 70,000 volts. An outdoor sub-station contains two 1,600 KVA transformers, which reduce this voltage to 3,000 volts. Large motors are directly driven at this voltage; those of less power are driven at a further reduced voltage of 220 volts, through another set of transformers. A small part of the current is converted into direct current for a few motors requiring it.

The engineer for construction was D. Enrique Soler, who has successfully carried out several installations in Spain and South America.

Cement Companies' Dividends.

Germany.—The Portland-Cement und Kalkwerke Wilhelm Schlenkhoff A.G. (Western Association) has declared a net profit of R.M. 6,779 (£338) compared with R.M. 1,188 (£59) for 1929.

No dividends have been paid for two years by the A.G. Portland-Cement Werk Berka A. Ilm. (Northern Association), who made a loss of R.M. 93,000 (£4,650) in 1930 and a net profit of R.M. 6,321 (£316) in 1929. Similarly, no dividend has been paid by C.O. Wegener Rudersdorfer Portland-Cementwerk, G.m.b.H. (Northern Association), who have made a loss of R.M. 23,000 (£1,150) in 1930 and a profit of R.M. 21,000 (£1,050) in 1929.

Hochofen Lubeck A.G., Herrenwyck in Lubeckschen (Northern Association) declared no dividend for 1930 on a net profit of R.M. 1,300,000 (£65,000), but declared 6 per cent. for 1929 on R.M. 2,800,000 (£140,000).

U.S.A.—The net profits of the International Cement Corporation for the period January-September, 1931, amounted to $1,532,107 (£315,248) as against $3,446,766 (£709,211) for the same period in 1930.

The Alpha Portland Cement Co. declared a loss of $382,975 (£78,801) for the same period in 1931, and a net profit of $1,280,017 (£263,377) for 1930.

Over the January-September period the Pennsylvania-Dixie Cement Corporation also declared a loss for 1931 of $1,149,688 (£236,561) and a net profit for 1930 of $417,192 (£85,841).

(Note: All conversions are made at par.)

The Rotary Kiln in Cement Manufacture.—XI.

By W. GILBERT, Wh.Sc., M.Inst.C.E.

Recording Instruments.

(150.) DURING the tests carried out by the writer at various Portland cement plants it was usual to study the working of the kilns and the coal driers by the aid of recorders for temperature, speed, and draught. An examination of the charts thus obtained would usually show (as one result) the extent to which the working of the plant was irregular, and some of the more important improvements which were desirable were in this way made clear.

(151.) Reference is made in the first instance to a chart taken on a Cambridge quadruple-thread recorder which was attached to a coal drier, since it has a bearing on some of the calculations made in Articles IX and X. A

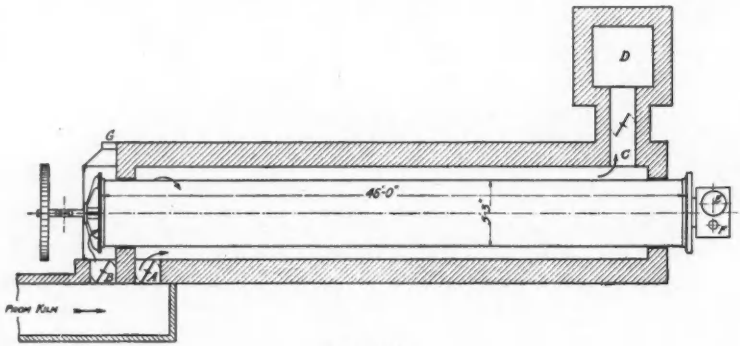


Fig. 45.

diagram of the drier shell with the encasing brickwork chamber is shown in Fig. 45. Hot air for drying was taken from a brickwork chamber at the upper end of the clinker cooler, and supplied directly to the exterior and to the interior of the shell by the flues marked A and B. The air left the brickwork chamber by the flue C, which led to the chimney D, and it left the shell interior by the chimney E. The raw coal entered the drier by the feed chute F, and the dry coal left the delivery hood at G.

A chart giving a record of the temperatures in the flues A, B, and C, and in the chimney E, is shown in Fig. 46. The temperatures in the flues A and B are the same. The upper half of the chart shows at any instant the temperature drop of the air as it passed through the brickwork chamber, the average value being 60 deg. F. The lower half of the chart shows in the same way the fall in the temperature of the air as it passed through the inside of the shell, the average temperature difference at the two ends being 338 deg. F. The temperature of the air drawn from the hot end of the cooler varied considerably since the kiln was frequently placed on half-speed, owing to an irregular feed of slurry, and the hot clinker did not enter the cooler at a uniform rate.

Taking into account the weight of air flow per minute, it was found that the quantity of heat given up inside the shell was about seven times the

quantity of heat given up outside the shell, so that this example taken from practice illustrates the advantage of bringing the hot air into direct contact with the cascading coal.

(152.) In concluding the subject of coal driers it should be mentioned that the drying research on granular materials, an abstract from which was given in paras. (102) to (110) of Article IX, was carried out by the writer for Messrs. Edgar Allen & Co., Ltd., of Sheffield, and the details are published by their permission.

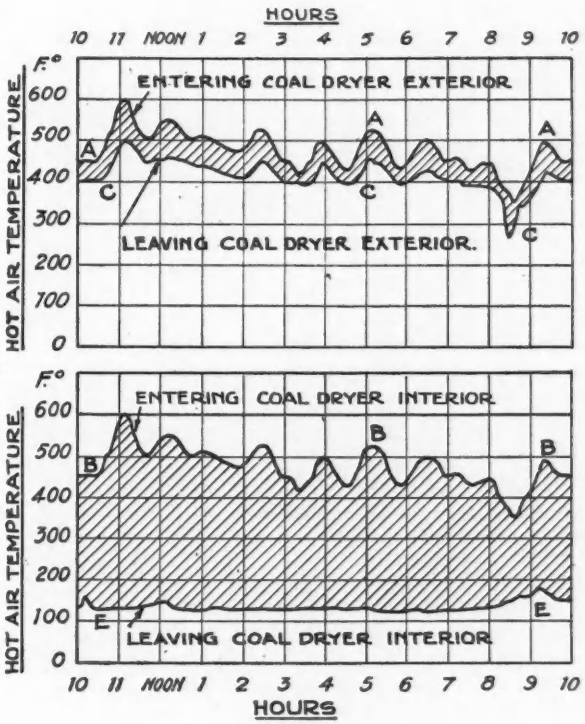


Fig. 46.

Relation between Kiln Speed, Rate of Feed and Charge, etc.

(153.) Before the various recorder charts which relate to rotary kilns are examined in detail it is desirable to clarify ideas on the following points:

(*a*) The relation which exists between the volume of materal fed to the kiln per revolution, the kiln diameter inside the lining, and the charge which is retained in it, the slope being fixed.

(*b*) The rate at which the charge moves down the kiln.

(*c*) The relation between the volume of the charge and the rate at which heat can be transferred to it.

The charge in the kiln is usually expressed as a percentage of the kiln volume, and in Fig. 47 charges of $\frac{3}{4}$, $1\frac{1}{2}$, 3, 5, 7, 9 and 12 per cent. are drawn to scale. The shaded area denotes a $\frac{3}{4}$ per cent. charge. It will be seen that a charge of slightly over 9 per cent. subtends a right-angle at the centre of the kiln.

It is useful to have a ready method of estimating the volume of the charge in a kiln from dimensions which can be measured on the site, and the diagram in Fig. 48 will be found suitable for the purpose. In the circle inset the charge is represented by the shaded area, the kiln diameter is taken as 100, and the diagram gives values of h, c, and ϕ for any charge up to 15 per cent The general arrangement of the scales and curves will be clear on inspection.

Example.—A kiln is 83 in. in diameter inside the lining, and the length of the chord c as measured on the site is 59 in.; what is the charge per cent.?

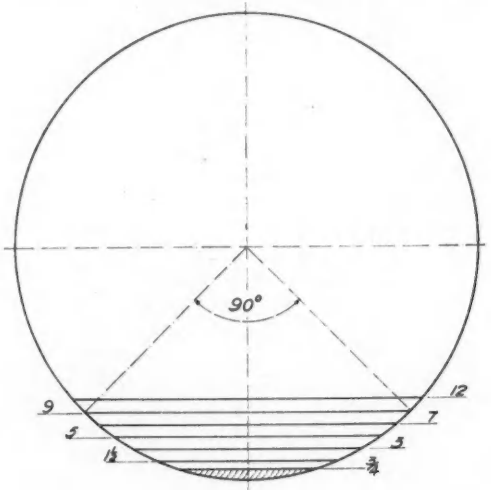


Fig. 47.

Values of c and h, as measured, must be replaced by their equivalent values to $d=100$ before using the graph. For $d=100$ the equivalent value of c is

$$\frac{100\times 59}{83}=71$$

and from the diagram, on line c, the charge is 9.3 per cent.

To construct the graph, values of h corresponding to any charge per cent. can be obtained from a table of segment areas, and values of c and of ϕ are then readily calculated.

(154.) It is evident that the relations which exist between the kiln diameter, the feed per revolution, the slope, and the charge per cent. would be costly to try out on a full-size kiln; it is therefore desirable to see to what extent the subject can be elucidated by the use of models.

As a preliminary step the apparatus shown in Fig. 49 was made. Three tubes were used, the inside diameters being 2 in., $2\frac{1}{2}$ in., and 3 in. respectively

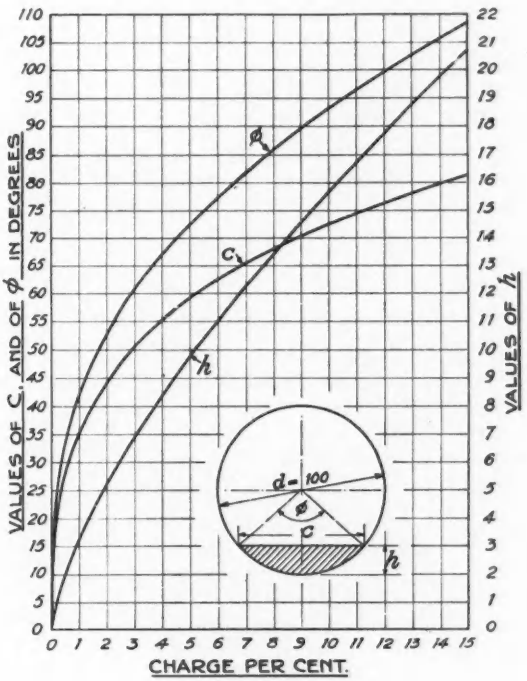
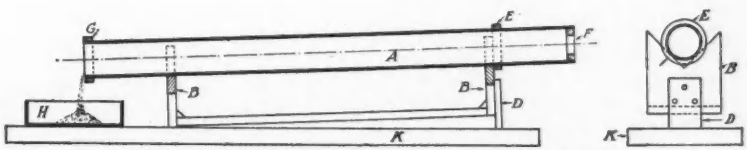


Fig. 48.



REFERENCE:— *A*, MODEL TUBE. *B*, END PIECES WITH V SUPPORTS. *D*, ADJUSTABLE SUPPORT. *E* COLLAR *F* & *G*, HARD WOOD RINGS. *H*, TRAY FOR SAND. *K* BASE PIECE LEVELLED UP

Fig. 49.

and the length 30 in. They were made of millboard and were reasonably straight and true. Turned hardwood rings could be inserted in the end of each tube at *G* to restrict the outlet as desired. The material used for experimenting was dry standard sand.

(155.) To illustrate the use of the model, a test made on a tube 2 in. in diameter with a free outlet is next described. The baseboard *K* was levelled and the support *D* adjusted to give the tube a slope of 1 in 25. Two ccs. of standard sand were put just inside the tube at the feed end; it was then turned slowly for two revolutions by hand, suitable lines on the collar *E* and on the support *C* enabling this to be done with precision. The cycle was repeated until the rate of delivery per tube revolution was equal to the rate of feed; the charge in the tube was then emptied out and measured, and found to be 67 ccs.

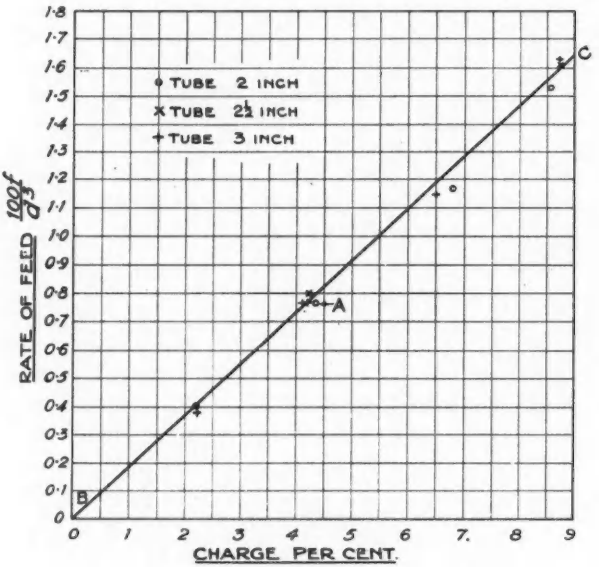


Fig. 50.

The tube dimensions in centimetres were: diameter = 5.08, length = 76.0, volume = 1,540, hence the charge per cent. was

$$\frac{100 \times 67}{1{,}540} = 4{\cdot}35$$

(156.) The result of this experiment (and of several others made on the three tubes) is plotted in Fig. 50. Values of $\frac{100f}{d^3}$ were plotted against the charge per cent.; the feed per revolution in ccs. is denoted by f; and d represents the tube diameter in centimetres. The experiments showed that when testing tubes of various diameters, if the rate of feed were made proportional to d^3 each tube would retain the same charge per cent. Hence the method of

plotting adopted enabled experiments on tubes of various diameters to be represented by a single line. In the experiment described

$$\frac{100f}{d^3} = \frac{100 \times 1}{(5.08)^3} = \frac{100}{131} = 0.765.$$

On Fig. 50 the experiment is represented by point A, where the figure 0.765 is plotted against the percentage charge of 4.35.

(157.) The series of points which represents the experiments on the 2 in., 2½ in., and 3 in. diameter tubes, with unrestricted outlets, at a slope of 1 in 25, are seen to come fairly well on to the line BC. Since this line passes through the origin, it follows that the charge per cent. which is retained in any given tube is proportional to the rate of feed per revolution.

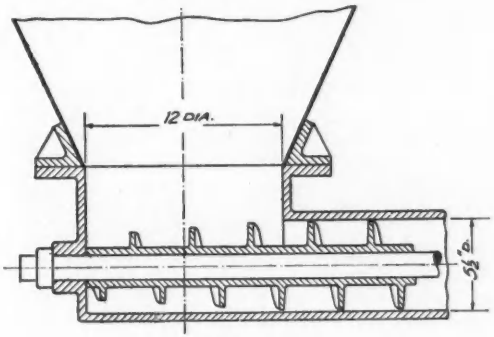


Fig. 51.

From the experiment quoted in (155) we may obtain the rate at which the charge moves along the tube.

Let M = movement of charge along the tube per revolution,
f = feed per revolution, and
Ac = area of charge in cross section,
then (working in centimetres) the quantity of sand delivered per revolution is $Ac \times M$, and this quantity must be equal to the rate of feed. Hence

$$Ac \times M = f \text{ or } M = \frac{f}{Ac} \quad .. \quad .. \quad .. \quad .. \quad (21$$

The tube diameter was 5.08 cm., and the area in cross-section 20.26. The charge is 4.35 per cent. Hence

$$Ac = 20.26 \times \frac{4.35}{100} = 0.881$$

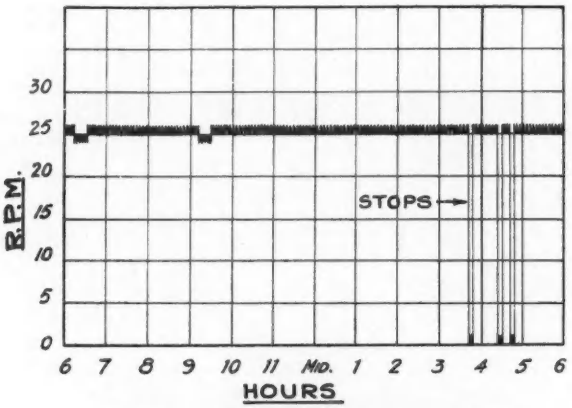
$$\text{and } M = \frac{f}{Ac} = \frac{1}{0.881} = 1.13$$

That is, the charge moves down the tube at the rate of 1.13 cm. per revolution.

(158.) It is convenient to express the movement of the charge per revolution as a percentage of the diameter of the tube, so that in this case we have

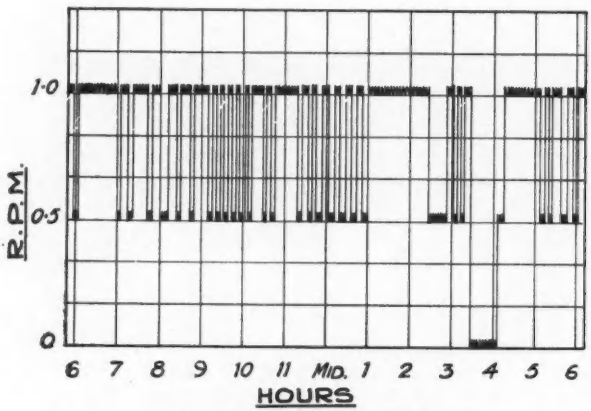
$$Mpd = \frac{1.13 \times 100}{5.08} = 22.2$$

where Mpd denotes movement of charge per cent. diameter.



COAL FEED SCREW R.P.M.

Fig. 52.



KILN SPEED CHART

Fig. 53.

Experiment shows the above result to be true in the case of the three tubes used for all charges up to 9 per cent., and it would probably be true for a tube of any other diameter made of the same material, inclined at 1 in 25, and fed with standard sand. The movement of the charge per revolution is much greater than would appear probable at first sight. The experimental results are, however, consistent, and a satisfactory explanation remains to be found.

(159.) The point *A*, which represents one experiment only, does not fall exactly on the line *BC* in Fig. 50, but an average value of Mpd may be deduced from any point in that line by proceeding as in (157). Making the calculation, it will be found that

$$Mpd \text{ (average value for three tubes)} = 23.3.$$

As an example, we may calculate the time required for the charge to pass through a tube 8 ft. diameter inside and 250 ft. long when it is making 0.74 r.p.m., the slope being 1 in 25. There is no contraction in area at the outlet end. The advance of the charge per revolution is $0.233 \times 8 = 1.86$ ft. The charge passes through the kiln in

$$\frac{250}{1.86} = 135 \text{ revolutions,}$$

and the time required is

$$\frac{135}{0.74} = 183 \text{ minutes.}$$

(160.) The question naturally arises as to whether the relation of the movement of the charge per revolution to the diameter, which has been deduced from the models, will be true for a rotary kiln. In the model tubes with standard sand in contact with a millboard surface, as each tube revolved the charge was maintained in circulation and the particles of sand continually rolled down the exposed face of the charge, as the material may be seen to do in a rotary kiln. The impression was formed that if the lining of a rotary kiln is reasonably free from indentations, and the material dry on the surface, the results would be applicable; it is, however, desirable to obtain values of Mpd from rotary kilns working under various conditions of slope, type of material, and condition of lining, as opportunity occurs.

Test on a Glass Tube.

(161.) To test the effect of a perfectly smooth surface, a glass tube 2 in. in diameter and 30 in. long was obtained. On trying the glass tube, at a slope of 1 in 25, and with a feed of standard sand, it was found that the charge did not circulate, but travelled round bodily with the tube for a short distance, and then fell back, so that the same particles of sand were always uppermost. The same effect may be noticed in the end of a clinker cooler where the steel lining-plates are too smooth to turn the clinker over on itself. The experiments made on the glass tube with a free outlet were not so consistent as those made on the millboard tubes. For instance, when $\frac{100f}{d^3}$ was made equal to 1.6, the charge retained in the glass tube varied in different experiments from 6.5 to 7.5 per cent., whilst in the millboard tubes it was 8.75 per cent.

Taking an average value, the rate of advance of the charge per revolution was 28 per cent. of the diameter, or, in the notation used, $Mpd = 28$. It will be seen that the substitution of a perfectly smooth lining for a millboard lining increased the value of Mpd from 23.3 to 28.

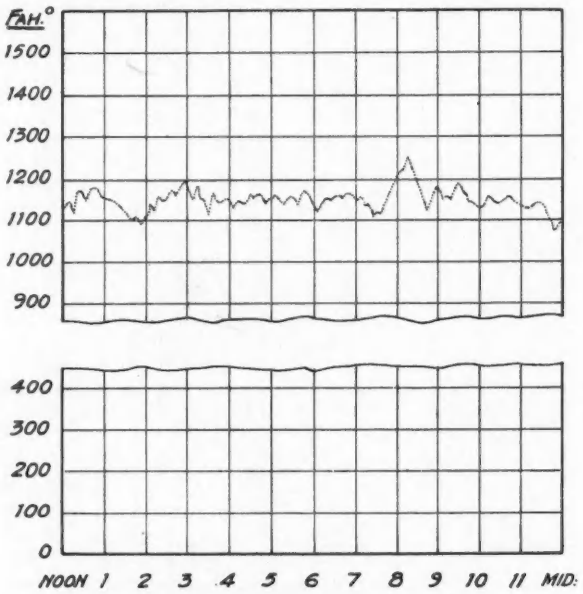
Summary of Tests on Millboard Tubes with Free Outlets.

(162.) For tubes operating at a slope of 1 in 25 and using standard sand up to charges of 9 per cent., it is found that

(*a*) The charge retained in the tube is strictly proportional to the rate of feed per revolution.

(*b*) Using tubes of various diameters, if the volume of the feed per revolution is made proportional to the cube of the diameter, the percentage charge retained in each tube will be the same.

(*c*) The rate of advance of the charge is independent of the charge volume and is equal to 23.3 per cent. of the diameter per revolution.



KILN EXIT GAS TEMPERATURE

Fig. 54.

It is proposed to return to this subject later in order to deal with the effect of restricted outlets and enlarged clinkering zones on the charge per cent. and on values of Mpd.

The bearing of the percentage charge in the kiln on the rate at which heat can be transmitted to it is dealt with in a preliminary way in Article XII.

A description of the application of recording instruments to kiln plant *A* now follows.

Kiln Plant "A."

(163.) The first kiln selected for illustration operated on the dry process. The shell was parallel throughout, being 6 ft. 11 in. diameter inside and 97 ft. 6 in. long. The firebrick lining was 6 in. thick for a length of 70 ft. and 4½ in. thick

for the remainder of the kiln. The test was of special interest on account of the low coal consumption, which was 18.8 per cent. of standard coal. The clinker output was 45 cwt. per hour, or a unit output of 16.5. The heat economy has usually been attributed to the rather large percentage of iron in the raw material, the ratio $\frac{SiO}{R_2O_3}$ being 1.77. The temperature in the kiln clinkering zone, as estimated by a Fery radiation pyrometer, was only 2,300 deg. F.

The percentage of $CaCO_3$ in the dry raw meal as fed to the kiln varied from 73 to 77 per cent. throughout the test of one week, but the cement produced was in all respects satisfactory.

(164.) **Coal Feeding Apparatus.**—The fine coal was stored in a small circular hopper with a conical base inclined at 65 deg. to the horizontal. The hopper was kept full, or nearly so. The feed screw was $5\frac{5}{16}$ in. diameter by $3\frac{5}{8}$ in. pitch, and was provided with a circular shroud pipe 21 in. long. The speed range of the screw was from 18 to 30 r.p.m. A diagram of the arrangement is shown in Fig. 51. During the kiln test of one week a speed recorder was driven from the feed-screw shaft, and a length of chart covering a period of twelve hours is shown in Fig. 52.

Contrary to the usual practice, the feed screw was allowed by the kiln burners to run at a constant speed for nearly the whole of the time, and it is therefore probable that a reasonably uniform coal feed was being obtained. If the coal had flushed past the feed screw from time to time its speed would have been reduced by the burner in order to prevent black smoke leaving the chimney, since the excess air used for firing was small. If the coal hung up in the base of the hopper, as is usual, it would at times do so when the kiln was on the slow speed, in which event the r.p.m. of the coal screw would be increased since there would be no other method of supplying the necessary heat to the material in the kiln. The chart shown in Fig. 52 is, however, characteristic, and indicates no change in the coal screw speed, hence it is concluded that the delivery per revolution was approximately uniform.

(165.) **Kiln Speed.**—The kiln was provided with two speeds, namely, 1 r.p.m. and $\frac{1}{2}$ r.p.m. The slope of the kiln was 1 in 25. A speed recorder was driven from a countershaft of the kiln gearing, and Fig. 53 shows a length of chart which covers a period of twelve hours. It will be seen that the kiln was frequently placed on half speed as relatively underburned material approached the clinkering zone, but there appeared to be no difficulty in making clinker. The dry raw meal was fed to the kiln from a small circular hopper having a conical base inclined at 65 deg. to the horizontal; the feed screw was 10 in. in diameter, and provided with a circular shroud pipe 4 ft. 9 in. long. The screw was usually operated at one speed.

(166.) **Kiln Exit-Gas Temperature.**—A length of chart covering a period of twelve hours is shown at Fig. 54. The thermo-couple was enclosed in a steel sheath $\frac{5}{8}$ in. in diameter, which was placed in a vertical position opposite the opening in the kiln end and about 4 in. in front of it. The average reading throughout the test was 1,141 deg. F. In the position in which the pyrometer was placed, the sheath could radiate to surroundings, the average temperature of which was estimated at 1,000 deg. F. Making the necessary calculation, the true average gas temperature is found to be approximately 1,267 deg. F., or an error of 126 deg. F. At the time the test was made a pyrometer suitably shielded from radiation loss was not available.

It is proposed to show in the next article what information about the working of kiln plant A can be derived from the recorder charts illustrated in Figs. 52 to 54.

Recent Patents Relating to Cement.

Rotary Cooling Drums. KRUPP GRUSONWERK AKT.-GES., F., Buckau, Magdeburg, Germany. (Assignees of Stehmann, H., 2, Langestrasse, Südende, Berlin.) Jan. 18th, 1930. No. 338,069.

The interior of a rotary drum (*p*) for cooling material discharged from a rotary furnace is connected with the exterior or with another portion of the interior of the drum by a shut-off compartment (*a*) within the drum; a partition (*l*) within the drum has an opening (*n*) receiving the material for supply to the compartment, the inlet and outlet openings (*b*, *c*) of which are actuated alternately and automatically. Air is admitted to the drum by a stationary tube (*k*) which carries a cam (*e*, *f*) engaging rollers (*h*, *i*) on levers carrying flaps (*d*, *g*) normally spring-pressed against the openings (*b*, *c*). The annular concentric chamber (*a*) is placed at one end of the inside of the drum, and that part of the drum surface not covered by the compartment carries blades (*q*) for raising the material. The drum may contain several compartments (*a*), which may be of helical or other form.

FIG.1.

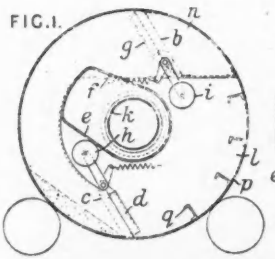
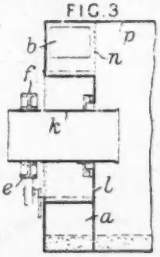


FIG.3



ROTARY COOLING DRUMS.

Ball Mills. WOODROFFE, F. K., 27, Clevedon Mansions, Highgate Road, Kentish Town, London. July 17th, 1929. No. 336,021.

In a ball mill means are provided above the horizontal axial plane to direct the balls inwardly so that they fall to the lower part of the cylinder. The cylinder (3) is rotatably supported by hollow trunnions (2) in which are mounted hollow trunnions (4)

"SIROCCOFIN" GILLED TUBE AIR HEATER

A magnified view of the "Siroccofin" Tube, shewing the copper fin helically wound round the tube.

Write for Catalogue No. 30

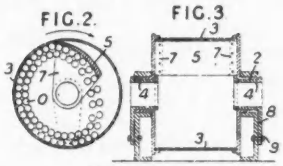
DAVIDSON & CO., LTD.

Sirocco Engineering Works, Belfast.

LONDON, MANCHESTER, BIRMINGHAM, NEWCASTLE, BRISTOL, CARDIFF, GLASGOW

TRADE SIROCCO MARK

connected at each end to internal and external arms (7, 8), respectively. The internal arms (7) are connected by a plate (5) which deflects the balls to the lower part of the cylinder and the external arms (8) are provided with slots and adjusting bolts (9) to position the plate (5), the bolts are

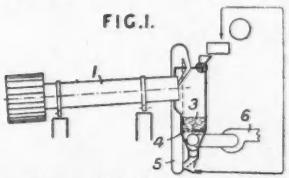


BALL MILLS.

adapted to be sheared when an obstruction occurs between the plate (5) and cylinder (3). The cylinder (3) is revolved fast enough to maintain the balls (o) in contact with the cylinder through centrifugal force. The front part of the plate (5) may be hinged and maintained in position by a spring, or the whole plate may be hinged intermediate of its length and be forced outwardly by a spring against a stop. In a further modification the plate may be supported slidably on a rod, the upper serrated edge being forced into contact with the cylinder by a spring on the rod. The internal arms may be supported on a steel bar passing through the cylinder trunnions and this bar may be hollow and perforated to carry away the ground material by air currents. Specification 234,520 is referred to.

Portland Cement. NIELSON, N., 32, Vestergade, Copenhagen. October 21st, 1929. No. 341,875.

Slurry is drained, granulated and then dried and partially or completely calcined by being preheated in a chamber wherein the combustion gases from the rotary kiln penetrate the granulated material. As shown in Fig. 1, the combustion gases leaving the kiln (1), pass downwards through a layer of the granulated material (3) supported on



a movable grate (4), from whence the material is conveyed by an elevator (5) to the kiln. The gases are removed by a suction fan (6). In further embodiments the material is supported on a travelling chain grate, and in a chamber fitted with a partition made to deflect the combustion gases.

Notes from Abroad.

Enlargement of Czecho-Slovakian Works.

The "Union" Zementfabriks A.G. has under consideration plans for the extension of the works at Stupava (Slovakia).

New Persian Works.

We learn that Messrs. F. L. Smidth & Co., Ltd., have secured the contract for the construction of the cement works at Shah Abdul Azim, near Teheran, and that a start has been made.

New Turkish Cement Works.

We learn from a contemporary that it is proposed to erect a cement works at Kerassunt, and that German and Turkish capital is interested in the undertaking.

New Cement Works in Tunis.

We understand that the erection of a Portland cement factory at Djebel-Djelloud has been commenced. The plant is being supplied by Messrs. F. L. Smidth & Co., Ltd.

Proposed Yugoslavian Cement Works.

We understand that the Beocinska Fabrika Cementa A.K.C. is proposing to erect a works at a cost of 18,000,000 dinar.

Trade Notices.

Screens.—Messrs. Holman Bros., Ltd., of Camborne, have issued a new catalogue illustrating and describing the James screen. These vibrators are built for heavy duty. The mechanism runs in an oil bath in a weather-proof housing which requires no further protection if installed out-of-doors. All the parts which require oil are in the vibrator, so that there are no auxiliary pivots or parts to require oiling. All parts of the screening surface are vibrating equally, so that not only is the screening capacity large but the screening action does not depend upon whipping or bending of the screen cloth. Two different types of machines are made, each having its own particular application.

Diesel Locomotive.—Messrs. Ruston & Hornsby, Ltd., of Lincoln, are now marketing a new type of narrow-gauge locomotive particularly suitable for the hard wear and tear encountered in handling materials in cement plants. A new type of gear box is used by means of which a single lever operates the clutch and gear change without foot action. The power unit is a 10 h.p. Diesel engine. There are three speeds, namely, 2½, 4, and 6 miles per hour, in either direction. The gears are in constant mesh and each speed is put into action by its own clutch. There is thus no possibility of damaging the gear box, which is foolproof; the loco. while travelling in top gear may be put directly into reverse by a single movement of a hand lever without bringing the machine to a standstill before reversing. As it uses heavy oil fuel, the loco. is particularly economical to run.

Change of Address.—Messrs. Robert Hudson, Ltd., have removed their London Office to No. 21, Tothill Street, S.W.1 (Telephone: Victoria 1324; Telegraphic address: Raletrux, Parl, London).

INDEX TO ADVERTISERS.

Allen, Edgar, & Co., Ltd.	ix	McEwan, J., & Co., Ltd.	vii
Avery, W. & T., Ltd.	xiii	Menck & Hambrock	—
Babcock & Wilcox, Ltd.	xviii	Metropolitan-Vickers Electrical Co., Ltd.	xxiv
Brown, John, Thos. Firth & Co., Ltd.	ix	"Miag" Mühlenbau und Industrie, A.-G.	x, xi
Chemisches Laboratorium für Tonindustrie	xii	Mining & Industrial Equipment, Ltd.	—
Constantin, E., Ltd.	iv	New Conveyor Co., Ltd.	xii
Crompton Parkinson, Ltd.	—	Newell, Ernest, & Co., Ltd.	Front Cover
Davidson & Co., Ltd.	46	Pearson, E. J. & J.	—
Davison, Charles, & Co., Ltd.	xxiii	Polysius, G.	vii
Diamond Lubricating Co., Ltd.	—	Renold, Hans, Ltd.	xvii
Dowdings, Ltd.	xxvi	Richter, Oscar A.	—
Evrard, F., & R. Frère	—	Rolland, John, & Co.	xxii
Ewart Chain Belt Co., Ltd.	v	Ross Patents, Ltd.	xvi
Fellner & Ziegler	xiv	Ruston-Bucyrus, Ltd.	xix
Firth, Thos., & J. Brown, Ltd.	ix	Ruston & Hornsby, Ltd.	—
Fraser & Chalmers Engineering Works	—	Seck Machinery Co., Ltd.	x, xi
Frère, R., & F. Evrard	—	Smidth, F. L., & Co., Ltd.	ii, iii
Fuller Company	iv	Stein, John G., & Co., Ltd.	—
General Electric Co., Ltd.	—	Taylor, J. Darnley, & Co., Ltd.	xiv
Glover, W. T., & Co., Ltd.	vi	Tonindustrie, G.m.b.H.	xii
Helipebs, Ltd.	viii	Vereinigte Stahlwerke, A.-G.	xxv
Holman Bros., Ltd.	xvii	Vickers-Armstrongs, Ltd.	xx, xxi, xxvii
Hudson, Robert, Ltd.	viii	Visco Engineering Co., Ltd.	xxvi
Klöckner-Werke, A.-G.	—		
Krupp Grusonwerk	xxii		